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AIR FLOTATION-BIOLOGICAL OXIDATION OF SYNTHETIC RUBBER AND LATEX WASTEWATER

A. H. King, et al

Firestone Synthetic Rubber and Latex Company

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The operation of a secondary waste-water treatment facility for treatment of the combined waste-water from Firestone's Lake Charles, Louisiana synthetic rubber manufacturing plant was studied for a period of nine months. The waste-water treatment facility was designed to treat an average daily flow of 3.4 mgd and a BOD load of approximately 2,000 lbs/day. The report describes the laboratory and pilot studies that were performed during the process development phase of the project and presents design data, operational data, and treatment cost data for the full scale facility. The effluent BOD concentration averaged 11.5 mg/l, with a suspended solids content of 29 mg/l. The BOD removal rate coefficient averaged .067 mg/l/day with an average BOD loading rate of .548 lbs BOD/day/lb MLSS. Capital costs including construction for the treatment facility ware $1,472,528. Operational, maintenance, and depreciation costs were $.499/1,000 gals. of raw waste-water treated, excluding sludge disposal costs. (EPA)

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ABSTRACT

The operation of a secondary wastewater treatment system at Firestone's Lake Charles, Louisiana Synthetic Rubber Plant was studied for a nine-month period. The system was designed to reduce the five-day Biochemical Oxygen Demand (BOD_5) by 90 percent to a 7 mg/l level and reduce Suspended Solids by 95 percent to a 10 mg/l level. An average BOD_5 reduction of 84.2 percent and Suspended Solids reduction of 85.2 percent was accomplished during the demonstration period.

The raw wastewater flow is 3.55 million gallons per day, and consists primarily of salt brine, dilute acid wastes, boiler water blowdown, dilute latex, and coagulated rubber solids. The average raw waste concentrations are: BOD_5, 72 mg/l; Chemical Oxygen Demand (COD), 447 mg/l; Suspended Solids, 197 mg/l.

The wastewater treatment system includes neutralization, coagulation and flocculation, primary clarification, biological treatment, final clarification and sludge impoundment. Primary and secondary clarification is accomplished by dissolved air flotation. A completely mixed aerated lagoon provides the necessary biological treatment.

The treatment plant cost was $1,473,000. The total project cost was approximately $2,000,000, since it was necessary to separate process wastewater from storm water. This separation was necessary to avoid treating large quantities of rain water contaminated with process wastewater. The average operational, maintenance, and depreciation costs were $0.499 per 1,000 gallons of wastewater treated.

This report was submitted in fulfillment of Project Number 12110 GLP under the partial sponsorship of the Environmental Protection Agency.

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SECTION I

CONCLUSIONS

The wastewater treatment facility at Firestone Synthetic Rubber and Latex Company's Lake Charles, Louisiana plant was studied for a nine-month period from October 1, 1971 through June 30, 1972. The following conclusions were reached based on the results of the study presented in this report.

1. A completely mixed aerated lagoon was an effective and acceptable means of removing oxygen consuming pollutants from the wastewater. An average overall BOD_5 removal of 84.2 percent was accomplished during the study period.

2. Dissolved air flotation was the only effective means of solids removal that produced a high quality effluent. An average overall suspended solids removal of 85.2 percent was accomplished during the study period.

3. Conventional sedimentation methods were not successful in clarifying plant wastewater.

4. Chemical treatment of the wastewater was necessary to remove colloidal materials and to provide an effective floc for initial and final dissolved air flotation clarification.

5. Final dissolved air flotation clarification was required to produce a high quality effluent and to prevent sludge auto-oxidation.

6. Turbulence within the chemical coagulant and precipitation treatment system had an adverse effect on solids removal during clarification and increased the amount of chemicals required to produce an effective floc.

7. Cleaning of the primary clarifier was necessary every four to six weeks due to the accumulation of solids. The final clarifier only required cleaning every ten to twelve weeks due to the solids concentration of the lagoon effluent and the nature of the effluent solids.

8. Carbon black particles present in the wastewater had an adverse effect on float stability during air flotation and required higher alum dosages for effective clarification.

9. Wastewater pH had a definite effect on clarification efficiency. Initial wastewater pH adjustment resulting in a 6.5 to 8.0 pH after chemical treatment provided the best environment for effective floc formation.

10. The average substrate removal rate coefficient (k) was found to be 0.067 l/mg-day, indicating that the wastewater was amenable to rapid biological oxidation. This compares with sewage having a range between .017 and .042 l/mg-day. (7)

11. A lagoon retention time of approximately one day was found to provide maximum BOD reductions. Longer retention times resulted in lower BOD removals due to relatively low organic loading ratios and sludge auto-oxidation.

12. Lagoon dyke construction must be such that it will withstand the degree of turbulence necessary to maintain a completely mixed regime.

13. Sufficient concentrations of nitrogen, phosphorus, and other essential nutrients were present in the wastewater to support biological activity without supplemental nutrient addition.

14. The ambient air temperature had little effect on aerated lagoon performance. The relatively short stabilization period and the temperature of the raw wastewater maintained adequate lagoon temperatures for efficient lagoon operations all year long.

15. Capital costs, including construction, were $1,473,000 for the wastewater treatment facility. Operational, maintenance, and depreciation costs were $0.499 per 1,000 gallons of wastewater treated, excluding sludge disposal.

16. The average sludge generation was 6.34 gallons/ 1,000 gallons of wastewater treated.

SECTION II

RECOMMENDATIONS

DESIGN MODIFICATIONS

The operation of the waste treatment facilities could be improved and the operating and maintenance cost could be reduced if a number of engineering and operational adjustments could be implemented, as follows:

Raw Wastewater Equalization - Adequate equalization as a first step prior to pH adjustment, chemical coagulation and flocculation, and primary clarification, is definitely recommended. Equalization would result in improved pH control for alum coagulation, more economical usage of neutralizing reagents, coagulants, and flocculants, and more efficient operation of the primary air flotation unit.

Equalization would reduce or eliminate frequent variations in wastewater characteristics such as pH, flow rate, influent suspended solids, BOD, and COD. Acid usage for pH control would be almost completely eliminated, since the equalized wastewater pH would be slightly acidic. As a result, caustic usage would be reduced in an amount equivalent to the reduction in acid usage. In addition, the over-feed of coagulants and flocculants would be reduced due to a reduction in the amplitude of variations in the chemical demands of the influent wastewater.

Air flotation units, particularly this installation, are sensitive to changes in flow. Due to the narrow width of the effluent weir, large variations in the water level within the flotation compartment result in poor removal [illegible] floating solids. Variations in the influent will also cause corresponding variations in percent recycle and the air-to-solids ratio. This installation has provisions to maintain a fairly constant influent flow to the primary air flotation unit by recirculating part of the clarified effluent; however, the desirability of adequate equalization is not diminished from an economic standpoint since equalization would result in substantial savings from reduced chemical usage.

Reduction of Turbulence - Revisions are recommended in the design of the flow measuring and flash mixing facilities to eliminate or reduce the high degree of turbulence in the wastewater after floc formation.

High shear and turbulence are inherent in the design of the flow measuring boxes. The primary flow measuring device consists of orifices cut in a partition within the flow measuring box. The orifices have a free discharge. The flow is determined by the head of water above the center line of the orifices on the upstream side. The high velocity of the water as it cascades from the orifices against the opposite side and bottom of the box imparts turbulence that is detrimental to the floc that has already been formed. Also, the 20-inch outlets in the bottom of the flow measuring box allow air entrained with the cascading water to be carried down to the bottom of the flash mixing tank, producing a high degree of agitation within the tank.

Due to the fact that the outlet nozzles of the flash mixing tanks are five feet higher than the inlet nozzles of the air flotation units, there is a siphoning effect within the 20-inch lines between the flash mixing tanks and the air flotation units. The siphoning action draws air into the water at the outlet of flash mixing tanks, entraining it with the water that is discharged into the distribution flumes of the air flotation units. The entrained air causes a high degree of agitation within the inlet distribution flumes.

It is therefore recommended that the flow measuring boxes be eliminated completely and that an alternate method be used to obtain flow measurements. Since the removal of the flow measuring tanks will cause an excessive difference in the water level between the alum coagulation vessel and the vessel immediately downstream, it is recommended that the alum coagulation vessel be equipped with a level controller and level control valve to keep its outlet nozzle flooded in order to eliminate the entrainment of air.

It is also recommended that the flash mixing tanks be equipped with level controllers and level control valves to maintain their water levels above their outlet nozzles, thus eliminating the turbulence within the inlet distribution flumes of the air flotation units caused by entrained air.

Care should be exercised in the design and layout of similar installations to eliminate conditions that may cause turbulence in the water after floc formation. It is recommended that no elevated vessels be utilized in the part of the treatment system handling floc-bearing water, although differences in elevation may appear to be insignificant. By this it is meant that the water level should be held approximately at the same elevation within all vessels from the point of chemical treatment through the outlet of the flotation compartment of the air flotation unit. Also, it is recommended that the velocity within interconnecting lines be held well below the turbulent flow range, with particular care being exercised to eliminate turbulence at the entrance and discharge points.

Settled Solids Removal - Due to problems encountered with settled solids within the air flotation units, it is recommended that settled solids removal equipment be installed in the flotation compartment of the primary air flotation unit. The 5° slope of the vessel bottom in the direction of water flow and the sludge collection troughs and blowdown headers are not effective in the removal of settled solids.

Aerated Lagoon Shape - It is recommended that in installations similar to this treatment system the aerated lagoons be of rectangular shape in order to obtain maximum benefit from mechanical aerators. Mixing, flow, and oxygen transfer are not evenly distributed throughout the lagoon due to its irregular shape. This allows short-circuiting of flow through the lagoon and allows solids to build up in stagnant areas. If a non-rectangular lagoon is already available, as was the case in this instance, this should be considered in equipment selection and design.

Lagoon Dykes - It is also recommended that when earthen dykes are used in the construction of an aerated lagoon, the inside slopes of the dykes be lined with a material suitable for the prevention of erosion of the dykes caused by wave action.

Future Requirements - Revisions to the primary and final clarification equipment for the reduction of turbulence is of primary concern, since clarification may be improved as well as operating cost lowered. These revisions are in the process of being made.

Additional testing is necessary to determine the return on investment possible if an equalization facility with adequate retention time was constructed.

Determination of the best means for disposal of the solids removed from the clarifiers is of paramount importance. An economically feasible method must be found to dispose of the solids without causing additional environmental problems. Additional sludge dewatering studies must be made to determine the most economical way of reducing sludge volumes.

SECTION III

INTRODUCTION

SCOPE

On February 1, 1971, the Firestone Synthetic Rubber and Latex Company was awarded a demonstration grant by the Environmental Protection Agency (EPA) under Section Six of the Federal Water Pollution Control Act, as amended. The grant, Number 12110 GLP, provided an amount not to exceed $392,288, over an 18-month period from February 1, 1971 to August 31, 1972, for the development, construction, and evaluation of a wastewater treatment system at the company's Lake Charles, Louisiana synthetic rubber plant.

The basic purpose of this project was to demonstrate the efficiency and economics of a system consisting of neutralization, chemical coagulation and flocculation, primary and secondary clarification, and mechanical aeration in the treatment of a synthetic rubber waste, particularly with respect to biological oxygen demand (BOD_5), chemical oxygen demand (COD), and suspended solids removal.

The specific objectives were to:

1. Demonstrate, in full scale plant operation, the BOD_5 and COD removal capabilities of a completely mixed aerated lagoon with a one-day retention time.

2. Demonstrate the effectiveness of dissolved air flotation clarification for the removal of suspended solids from a synthetic rubber waste.

3. Compare actual parameter removal capabilities with those projected during the process development phase of the project (i.e., 90% BOD_5 removal and 95% suspended solids removal).

4. Determine the capital, operating, and maintenance costs of a treatment system incorporating these features.

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BACKGROUND

At the Lake Charles plant, Firestone produces over 30 different types of emulsion and solution polymerized butadiene-styrene copolymers. Total daily production is about 800 long tons per day, of which approximately 60 percent is emulsion polymerized and 40 percent is solution polymerized.

Considerably less wastewater is generated by the solution polymerization process than by the emulsion polymerization process since a hydrocarbon solvent, rather than a soap solution, is used as the polymerization medium. In fact, approximately 85 percent of the total wastewater produced is generated by the emulsion process. Total daily final effluent flow averaged 3.55 million gallons per day over the demonstration period, excluding sanitary sewage, which was treated by a separate in-plant facility.

Treated plant effluent is discharged into Bayou D'Inde, which in turn empties into the Lake Charles Ship Channel on the Calcasieu River. The receiving waters are estuaries subject to salt water intrusion from the Gulf of Mexico.

The present secondary wastewater treatment facility began operation on May 27, 1971 after two years of research and development work. The basic wastewater characterization study, definition of the problem, and a conceptual design were done by Firestone with assistance from two consulting firms. Extensive laboratory and pilot work was performed by plant personnel in arriving at the final treatment plan and in generating the design data for the total wastewater treatment plant.

The treatment system installed was designed utilizing the data available from laboratory studies, pilot plant operation, and previous Firestone experience in the field of wastewater management. The system, including neutralization, chemical coagulation and flocculation, primary air flotation clarification, biological oxidation, and secondary air flotation, was designed to exceed effluent quality requirements set by the Louisiana Stream Control Commission.

SECTION IV

THEORETICAL CONSIDERATIONS

CHEMICAL COAGULATION

In waste treatment, "coagulation" is a chemical process which involves the addition of chemicals to effect the destabilization and aggregation of dispersed materials, usually in suspended or colloidal form.

Simple colloidal dispersions are two-phase systems. The five common types are gas-in-liquid, solid-in-liquid, liquid-in-liquid, solid-in-gas, and liquid-in-gas. The predominate phase is referred to as the dispersion medium. The colloidal particles are referred to as the disperse phase. Colloidal particles are usually defined as those ranging in size from about 10^{-6} to 10^{-8} centimeters. They do not settle on standing and cannot be removed by conventional physical treatment methods. The most significant characteristic of colloids is their large surface area-to-volume ratio. Because of this, the effects of surface phenomena, such as adsorption and electrostatic attraction, are magnified, and play a central role in determining the bulk physical properties and stability of colloidal systems.

Most colloids can be classified as either hydrophilic or hydrophobic. Hydrophilic particles have an affinity for water. Water molecules attach to hydrophilic colloids and form a layer around the particle which hinders close contact and therefore aggregation of colloidal particles. The affinity for water is often the result of the presence of polar groups on the surface of the particle. Particles of this type will assume a charge as a result of ionization, which depends on the pH of the medium. Conversely, hydrophobic particles have little affinity for surrounding water molecules. Since no solvation occurs, the stability of this type of colloid is due to the repulsive interaction of similarly charged colloids. In both cases the overall condition of electroneutrality must be satisfied. However, the localization of excess electrical charges around the particles and the attraction of counter-ions create an electrical double layer that causes the particle to act as if it were electrically charged.

Most colloids found in nature are negatively charged. The fixed negative layer is surrounded by a second layer of counter-ions. The electrostatic potential at the shear surface of the double layer is called the zeta potential. In general, the stability of colloids is dependent on the magnitude of the zeta potential. The dispersion remains stable so long as the zeta potential exceeds a critical value below which the factors tending to destabilize the colloid (gravitational and Van der Waals forces) come into play and promote aggregation.

The stability of colloids is due to the repulsive interaction of similarly charged particles and, in the case of hydrophilic colloids, to solvation. If the solvation is weak, the colloid can be destabilized by neutralizing the charge on the particles. This can frequently be achieved by adjusting the pH to the isoelectric point. At the isoelectric point the net charge on the particle is zero, and no double layer exists to produce a zeta potential. The repulsive force can also be reduced by adding ions or colloids of opposite charge to the colloidal system. This lowers the zeta potential and tends to destabilize the colloidal system.

According to the Schulze-Hardy rule, the valence of the counter-ion is important in its ability to destabilize colloids by zeta potential reduction. On a molar basis, bivalent ions are 10-50 times and trivalent ions about 300-700 times more effective than monovalent ions. Therefore, the most commonly used coagulants are those that produce trivalent ions, such as compounds of iron III and aluminum III.

For a given metal ion concentration, the rate and degree of coagulation depends on the pH of the medium. In addition, chemical coagulation is successful only when the concentration of metal ions is high enough to precipitate hydroxides. The hydroxide floc formed sweeps the dispersion together and entraps particles in the floc.

Coagulant aids are reagents used in conjunction with coagulants. These reagents, including polyelectrolytes, activated silica, and bentonite, serve to bind floc particles together by forming chemical bridges.

DISSOLVED AIR FLOTATION

Dissolved air flotation is a treatment method used for the removal and concentration of suspended solids, sludges, and other floating matter. There are three basic types of dissolved air flotation systems: (1) pressurization of the total influent liquid, (2) pressurization of part of the influent stream, and (3) recirculation and pressurization of a fraction of the clarified effluent. The Lake Charles plant uses the pressurized effluent system, and it will be

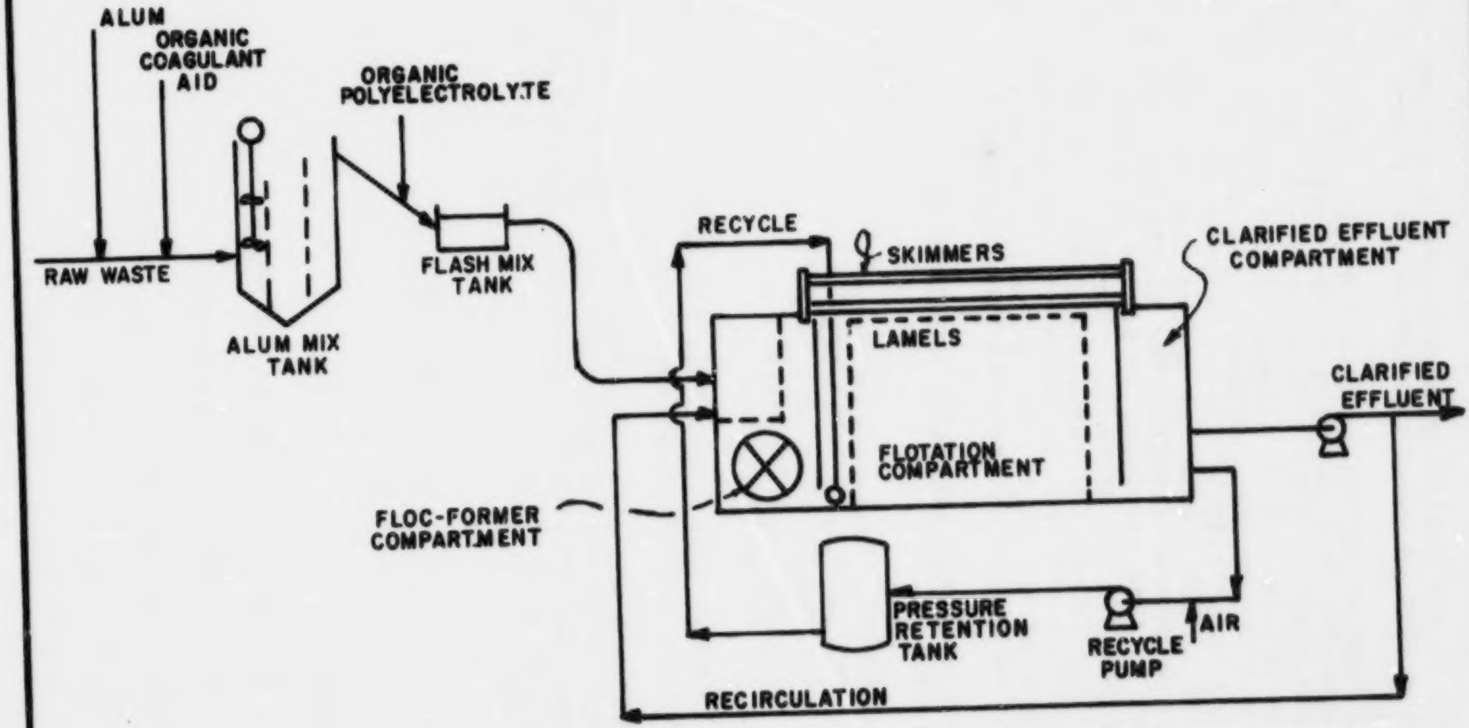
ALUM
ORGANIC COAGULANT AID
RAW WASTE
ALUM MIX TANK
ORGANIC POLYELECTROLYTE
FLASH MIX TANK
RECYCLE
SKIMMERS
CLARIFIED EFFLUENT COMPARTMENT
LAMELS
CLARIFIED EFFLUENT
FLOTATION COMPARTMENT
FLOC-FORMER COMPARTMENT
PRESSURE RETENTION TANK
RECYCLE PUMP
AIR
RECIRCULATION

FIGURE I

SCHEMATIC OF AIR-FLOTATION SYSTEM PRIMARY FLOTATION CLARIFIER implicit in the following discussion that a pressurized recycle system is being considered (see Figure 1).

In this type of system a portion of the clarified effluent is pressurized to 40-65 psig in the presence of enough air to approach saturation. This portion is then combined with the bulk liquid. Upon release of the pressurized air-liquid mixture to the atmospheric pressure of the flotation unit, the solubility of air in water decreases rapidly, resulting in the release of micron-size air bubbles from the supersaturated liquid. The minute air bubbles become enmeshed in floc particles or adhere to suspended solids, buoying them to the surface. Ferris wheel-type skimmers continually remove the resulting float from the surface. The clarified effluent is drawn off continuously from near the bottom of the unit. Periodically the unit is emptied and settled solids are removed from the bottom.

A flotation system generally consists of the following components:

1. Recycle Pressurizing Pump
2. Air Injection Facilities
3. A Pressure Retention Tank
4. A Sludge Removal Pump
5. The Flotation Unit

Figure 1 shows these components for one of Lake Charles' dissolved air flotation units.

The mechanisms and driving forces involved in solid-liquid separation by flotation are similar to those governing sedimentation. The application of Stokes' Law determines the floatability or settleability of a particle in a given waste. (9)

$$v = \frac{g D^2 (ds - d_1)}{18V} \qquad (1)$$

where:

g = Gravity constant, ft/sec^2

D = Diameter of particle, ft

d_s = Density of particle, lb/ft^3

d_1 = Density of liquid, lb/ft

V = Viscosity of liquid, lb/ft-sec

v = Particle separation velocity, ft/sec

When the particle separation velocity is positive, the particle settles. However, if the separation velocity is negative, the particle will float. In dissolved air flotation the density of the air-solid combination is less than the suspending medium, the particle separation velocity is negative, and the particle rises. The air bubble increases the difference in density between the particle and the suspending medium, thereby increasing the particle separation rate.

The performance of a flotation unit, in terms of influent and effluent solids concentrations, can be related by means of an air/solids ratio, defined as the mass of air released per unit mass of solids in the influent liquid. Although the amount of solids present can be determined analytically, the quantity of air released must be calculated from the absolute pressure and the air solubility. The solubility of air in water is directly proportional to the absolute pressure and inversely proportional to the temperature. Therefore, at a given temperature the theoretical quantity of air released when pressurized recycle is reduced to atmospheric pressure may be calculated from the following equation. (6)

$$s = s_a \left(\frac{f\ P_a}{14.7}\right) - 1 \qquad (2)$$

where:

s = Air released, cm^3/l

s_a = Air saturation at atmospheric pressure, cm^3/l

P_a = Absolute pressure, lb/sq in.

f = Fraction of saturation attained

The actual quantity of air released depends upon the turbulent mixing conditions at the point of pressure reduction and the accuracy of the assigned degree of saturation factor. The degree of saturation depends upon the design of the pressurization system, particularly the pressure retention tank. Conventional static designs usually yield up to 50 percent of saturation; whereas, up to 90 percent of saturation can be reached with the use of special packing or mixing.

The air/solids ratio can be calculated by the following equation.(6)

$$\frac{A}{S} = \frac{C\ s_a\ R\ (f\ P-1)}{Q\ S_a} \qquad (3)$$

where:

A/S = Air/solids ratio

C = Air density, mg/cm^3

s_a = Air saturation at atmospheric pressure, cm^3/l

R = Pressurized volume, liters/day

P = Absolute Pressure, atm

Q = Waste flow rate, liters/day

S_a = Influent suspended solids, mg/l

f = Fraction of saturation attained

SPECIAL DESIGN FEATURES

The major difference between the air flotation unit used by Firestone and a conventional air flotation unit is the use of lamels in the flotation compartment of the clarifier. The lamels allow higher loading rates in the unit without producing turbulent flow. The lamels are a series of parallel vertical baffles approximately four inches apart which rise from the bottom of the clarifier to near the normal water level (see Figure 1).

The lamels produce two specific effects. First, they reduce turbulence, eddies, and back-mixing. Second, the frictional resistance of the lamels provides a relatively calm area near the surface of the lamel where particles can rise to the surface without excessive interference caused by flow across the unit.

The lamel concept is based on the Reynolds theory in which mass velocity in an open channel is related to the hydraulic radius and the liquid viscosity.(13)

$$N_{Re} = \frac{4 R_h G}{V} \qquad (4)$$

where:

N_{Re} = Reynolds number

R_h = Hydraulic radius, ft

G = Mass Velocity, lb/sq ft-sec

V = Viscosity, lb/ft-sec

For a given Reynolds number, assuming the viscosity remains constant throughout the system, the only two variables are the hydraulic radius and the mass velocity, and the product of these two variables is equal to a constant value. Therefore, if the hydraulic radius of a given channel is decreased, the mass velocity of the liquid can be increased and still maintain the same Reynolds number.

It has been found that laminar flow exists below Reynolds numbers of 2100 and that turbulent flow exists for Reynolds numbers greater than 4000. Therefore, for a Reynolds number insuring laminar flow, higher loading rates can be maintained in a unit with lamels than in a conventional unit because of the smaller hydraulic radius. Stated another way, "By dividing the flotation chamber into a number of narrow channels, it is possible to increase the total unit flow without producing disturbing turbulence . . with proper use of lamels, flow rates can be achieved which are more than double those normally possible with conventional flotation equipment." (13)

PERFORMANCE CHARACTERISTICS

The six major variables of a dissolved air flotation system are as follows:

1. Recycle ratio
2. Pressure maintained in recycle system
3. Air/solids ratio
4. Retention time
5. Loading rate
6. Chemical feed rates

The percent of clarified effluent recycled back into the unit directly affects the amount of air that can be released. At the same pressure, a higher ratio can release more air into the flotation unit. However, increased recycle also increases the loading rate and decreases the retention time. In addition, high recycle rates may cause severe turbulence, which reduces unit efficiency.

The pressure maintained in the pressurizing system affects clarifier performance. Increased pressures produce higher air solubilities which enable larger quantities of air to be dissolved. However, economic considerations require that the pressure be maintained as low as possible without affecting unit performance. Also, higher pressures can produce turbulence and increase bubble size, both of which reduce unit efficiency. Pressures of 40-90 psig have been used, with 40-60 psig used most frequently.

The air/solids ratio must be high enough to insure that sufficient air is released to float all of the suspended matter. However, an excessively high air/solids ratio does not improve effluent quality, and in some cases can actually decrease effluent quality. The optimum air/solids ratio varies between different wastes, dependent on the nature of the solids, the quality of the air-to-solid bond, and the solids concentration.

The retention time also affects unit performance. There are two important retention times, the retention time in the pressurization system and the retention time in the flotation unit. Up to a point, the effluent suspended solids level decreases and the concentration of solids in the float increases with increasing retention time. A long retention time insures maximum air saturation in the pressure retention system and allows time for particles with low separation velocities to reach the surface. However, too long a retention time may allow the breaking of weak air-to-solid bonds, the breaking of air bubbles, and disintegration of the float.

Loading rates are related to retention time and unit size. For a particular unit, as the loading rate increases the retention time decreases, and vice versa. Under conditions common in chemical process industries, loading rates are designed on the basis of 2.5 gpm/ft of surface area in the flotation compartment for conventional flotation designs.(13)

If chemical flocculation is used, the chemical feed rates will affect effluent clarity. Generally, an optimum feed rate will exist, with a lower rate producing insufficient solids removal and a higher rate producing increased turbidity caused by excessive floc or large, bulky floc particles.

BIOLOGICAL OXIDATION

Biological wastewater treatment is nothing more than nature's self-purification process working under concentrated and controlled conditions. Biological treatment processes are used to remove organic matter from wastewater through the microbial metabolic processes of oxidation and cell synthesis.

Under aerobic conditions, micro-organisms use dissolved oxygen in the water to convert organic wastes into cellular matter, plus the energy needed to support cellular activity. In the process some cellular mass is also converted into energy or end products, particularly if there is a low food-to-micro-organism ratio. Endogeneous metabolism occurs in all cells in which energy is utilized for cellular activity. The amount of cellular matter consumed in endogeneous metabolism depends upon several factors, including food-to-micro-organism ratio, the average sludge age, and the waste characteristics. Endogeneous metabolism is represented mathematically by the coefficient "b", which has the units of reciprocal time, or a fractional decrease in cell mass per day.

When organic matter is removed from a waste by biological oxidation, two basic processes occur: (1) oxygen is consumed by the active biological mass for energy, and (2) new cell mass is synthesized. The organisms may oxidize a portion of their cellular mass as well as oxidize the organic portion of the waste. These reactions may be schematically represented by the following general relationships.(6)

$$\text{Organic matter} + O_2 + NH_3 \xrightarrow{\text{(cells)}} \text{New Cells} + CO_2 + H_2O \qquad (5)$$

$$\text{Cells} + O_2 \longrightarrow CO_2 + H_2O + NH_3 \text{ (Auto-oxidation)} \qquad (6)$$

Several mathematical models have been proposed to explain the mechanism of BOD_5 removal by biological processes. Almost all show that at high BOD_5 levels the rate of BOD_5 removal per unit of active biological sludge remains constant to a limiting BOD_5 concentration below which the rate becomes concentration dependent, and therefore decreases. The following rate equations have been offered for this concentration dependent phase.(6)

$$\frac{a}{X_a} \times \frac{dL}{dt} = kL \tag{7}$$

and

$$\frac{a}{X_a} \times \frac{dL}{dt} = kL^2 \tag{8}$$

where:

a = Volatile suspended solids synthesized per unit of BOD_5 removed, mg VSS_p/mg BOD_r

k = Substrate removal rate coefficient (or sludge growth rate), 1/mg-hr

L_e = Effluent BOD_5, mg/l

L_o = Influent BOD_5, mg/l

t = Aeration time, hours

X_a = Concentration of biological volatile solids, mg/l

Integrating (7), it becomes

$$\frac{L_e}{L_o} = e^{-k X_a t} \tag{9}$$

and (8) becomes

$$kL_e = \frac{L_o - L_e}{X_a t} \tag{10}$$

or rearranging and solving for "k", (6)

$$k = \frac{L_o - L_e}{L_e X_a t} \tag{11}$$

The data from most completely mixed systems in which the effluent BOD_5 concentration is low can be correlated according to equation (10). The removal rate coefficient is temperature dependent, as shown by equation (12). (6)

$$k_T = k_{20^o} \cdot \theta^{T-20} \qquad (12)$$

where:

θ = Experimental temperature coefficient
T = Temperature ^oC

The sludge yield from a biological treatment system can be estimated from the following relationship. (6)

$$\triangle X_v = S_o = \underline{a}L_r - bX_v \qquad (13)$$

where:

$\triangle X_v$ = Sludge yield, mg/l
X_v = Average MLVSS in system, mg/l/day
$\underline{a}$ = Cell yield coefficient, mg SS/mg $BOD_{\underline{r}1}$
b = Endogenous respiration constant, day
Lr = BOD_5 removal, mg/l
S_o = Influent VSS, mg/l

Sludge yield from biological oxidation may vary for several reasons. The "k" rate in the BOD_5 test may vary, depending on the characteristics of the waste and the microorganisms. Also, variations in the VSS content of the influent wastewater will influence the sludge yield. Probably most important, in most industrial wastes the rates and concentrations of the influent streams may change markedly during the course of the measurement period.

AERATED LAGOONS

A waste stabilization pond is "any pond system designed to fulfill a biological waste treatment requirement." (10) An aerated lagoon is a waste stabilization pond in which mechanical aerators supplement or replace algae as a means of providing the required dissolved oxygen. Oxygen is supplied to an aerated lagoon by the physical action of the surface aeration units and oxygen transfer through the air-liquid interface.

Aerated lagoons, usually six to 18 feet deep, can require up to 15 times less land area, and can improve efficiency by at least a factor of five compared to a conventional waste stabilization pond. They are less sensitive to system variations or shock loadings compared to other forms of biological oxidation processes (such as trickling filters) because of their large volumes. In an aerated lagoon, stabilization is accomplished by a dispersed-growth phase. Due to the dispersed nature of the culture, an aerated lagoon does not require extremely close control over operating variables such as temperature, pH, and organic loading.

Full advantage of the potential of the aerated lagoon can only be realized by installing sufficient aeration equipment to keep the system completely mixed as well as to satisfy the necessary oxygen requirements. If the turbulence level in the basin is increased to maintain solids in suspension, the system becomes analogous to an activated sludge process.

Since the active biological solids level in an aerated lagoon is low, BOD_5 removal is primarily a function of the retention time, temperature, and the nature of the waste. A small fraction of the BOD_5 is never removed, even after long periods of aeration, because an equilibrium is reached between synthesis and the release back into solution of cellular breakdown products caused by auto-oxidation.

SECTION V

PROCESS DEVELOPMENT

INITIAL WASTEWATER CHARACTERISTICS

Firestone, assisted by a consultant, measured and evaluated the plant's raw process wastewater in terms of flow, BOD_5, and other basic parameters. During this evaluation a continuous composite sampler was placed in the combined raw wastewater stream just above the final settling basin, and daily composite waste samples were collected for a 12-day period. A rectangular contracted weir was constructed in the final settling basin's outlet trench and total wastewater flow measured.

The final wastewater flow rates remained relatively constant during the study period; however, no rainfall occurred during this period. It should be noted that during this phase of work the plant storm water and effluent sewers were combined. Later measurements indicated very large increases in flow during and after a period of rain. Wastewater segregation was therefore an absolute prerequisite to the design of a wastewater treatment facility.

A complete wastewater flow study was conducted throughout the plant complex. As a result of this study, plans were initiated to design and install an entirely new network of effluent trenches and storm water ditches. The installation of the plant effluent distribution and collection system will not be discussed to any extent in this report since only the wastewater treatment system itself is under consideration.

After the initial wastewater characterization study was completed, the plant's laboratory facilities were expanded to allow complete and comprehensive in-plant wastewater testing. Average raw wastewater characteristics over the demonstration period are shown in Table 11.

WASTEWATER CHEMICAL STUDIES

Initial chemical treatment studies were conducted to determine if the wastewater required the addition of a coagulant or flocculant during primary clarification.

The raw wastewater contains trace amounts of colloidal materials in the form of latex, soap, oil, and similar emulsions that impart turbidity as well as add to the wastewater's oxygen demand. Other materials are present as very fine particles of rubber, talc, lime, and carbon black that exist as a fine-solid suspension. Effective clarification required the addition of a primary coagulant followed by a flocculant aid to remove the suspended and colloidal particles from the wastewater.

Various inorganic and organic coagulants were evaluated on samples of the plant's combined wastewater utilizing a six-paddle Phipps-Bird jar test apparatus. During these tests, the inorganic metallic salts of aluminum and ferric sulfate performed successfully as primary coagulants.

The cationic organic polyelectrolytes tested were not very successful during these tests. The inorganic metallic salt's ability to form a hydroxide floc provided much better clarification because of its ability to remove very fine solid particles.

Numerous polyelectrolytes varying in molecular weight and degree of charge were evaluated during the jar studies. The very high molecular weight, medium charged, anionic polyelectrolytes proved to be the most effective flocculants evaluated during the tests.

Aluminum sulfate (alum) was used as the primary coagulant since the chemical was already being used within the plant. Dosage rates of 30 to 150 mg/l were required for adequate clarification during the tests. Flocculant aid dosages of 0.25 to 1.0 mg/l were required.

Later jar tests were successfully run using a low molecular weight, high charge density, cationic polyelectrolyte in conjunction with alum. Tests performed with some of the higher molecular weight cationics were not successful due to their inherently lower charge densities.

The alum, however, could not be totally replaced by the cationic polyelectrolyte and still provide excellent effluent clarity. Small dosages of alum in conjunction with the cationic polyelectrolyte produced comparable results. Cationic polymer dosages of 2 to 3 mg/l with 10 to 20 mg/l of alum produced excellent effluent. The anionic polyelectrolyte dosages remained near those found during early jar tests.

LABORATORY AIR FLOTATION TESTS

Flotation tests were conducted to evaluate the feasibility of dissolved air flotation as a primary solids removal method. Samples were synthesized by mixing one part of carbon black wastewater with two parts of non-black wastewater to duplicate the effluent that would exist after installation of the new effluent distribution system. Pretreatment of the wastewater with a coagulant and flocculant aid was necessary during these air flotation clarification studies.

Additional laboratory air flotation tests were performed to determine if air flotation could be utilized as a secondary solids removal method. These tests were performed during laboratory bio-oxidation studies using samples of wastewater removed from the bio-oxidation unit. Effluent from the unit required the addition of a flocculant aid to bring about effective clarification during the flotation tests.

The following conclusions were drawn from the laboratory air flotation tests:

1. Pretreatment of the wastewater with alum followed by an anionic polyelectrolyte was required. Average dosage rates of 65 mg/l alum and 0.25 mg/l Betz 1110 were used during these tests. Alum dosages near 100 mg/l with polyelectrolyte dosages of 0.5 to 1.0 mg/l were required to treat successfully wastewater with abnormally high levels of carbon black.

2. Recycle pressurization was the only successful dissolved air flotation method. Total or partial pressurization of the wastewater and subsequent release into the flotation chamber resulted in floc break-up and poor solids flotation.

3. Recycle rates of 33-1/3% were used during most of the tests with very good results.

4. Clarified effluent proved to be more effective than tap water for use as the recycle stream. Surface active materials present in the clarified effluent produced a more dense, slower rising air blanket that was very effective in clarification.

5. Sludge rise rates were 1.5 to 2.0 ft/min during the flotation tests.

6. A recycle pressure of 50 psig gave the most effective air-water mixture. A recycle pressure of 30 psig produced too large an air bubble for good clarification. Pressures above 50 psig did not improve clarification.

7. Suspended solids removals of 90% were accomplished during the laboratory air flotation tests.

8. BOD_5 reduction during laboratory air flotation was around 28%. COD reduction was not determined.

9. Float stability was adversely affected by the presence of excess carbon black in the wastewater. A weak air-to-solid bond was observed when insufficient alum floc was present.

A limited number of tests were run on the wastewater from the laboratory secondary treatment studies; however, the following general conclusions were drawn from the tests:

1. The wastewater required pretreatment with a flocculant aid to produce a cohesive floc large enough for good flotation. The floc produced during biological treatment was dispersed and exhibited poor settling qualities.

2. The solids in the wastewater from the biological treatment unit proved to be amenable to air flotation, with good float stability and rise rates observed.

A laboratory air flotation test kit was purchased for conducting the latter air flotation tests. The test kit consisted of the following equipment:

1. Pressure Bomb - A quart stainless steel whipped cream dispenser equipped with a metal tire air valve in place of the cylinder piercing apparatus.

2. Flotation Chamber - A 500 ml graduated separating cylinder with a bottom stopcock valve for air introduction and effluent withdrawal.

3. Air Gauge - A 20-120 lb tire-type air gauge for determining bomb pressure.

The following additional equipment was also utilized in performing the tests:

1. A manual control air regulator installed on the plant laboratory air supply. An automatic type air chuck with flex hose was connected to the outlet of the regulator for bomb pressurization.

2. A Phipps-Bird six-paddle gange mixer with one-liter beakers was used during the chemical pretreatment work.

LABORATORY BIO-OXIDATION STUDIES

Initial laboratory biological treatment studies were conducted to determine the biodegradability of combined wastewater and a feasible biological process for treatment. Composite samples of the wastewater were tested to determine:

1. Toxicity of the wastewater from a biological standpoint.

2. Nutrient requirements for biological stabilization.

3. Oxygen requirements of a full-scale treatment system.

4. Oxygen uptake rates at various organic loadings.

5. BOD_5 loading ratio for biological treatment.

6. Retention time necessary during aeration.

The bio-oxidation studies were initiated by aerating mixtures of wastewater with activated sludge from a sewage treatment plant for a two-week period, gradually increasing the ratio of plant wastewater to sanitary wastewater until the volume of wastewater under aeration consisted of 100 percent plant wastewater. The acclimated organisms were then used as seed material for the laboratory lagoon studies. The bio-oxidation tests were carried out in five laboratory aerated lagoon units, each equipped with mixers and each having a two-liter capacity.

Initially the wastewater was fortified with nitrogen and phosphorus to insure proper ratios for microbial development. Later analysis of the wastewater indicated that it contained sufficient nutrients without fortification. Subsequent bio-oxidation studies were performed without fortification.

The laboratory units were fed wastewater on a continuous basis, varying retention times between one and five days and temperatures between 5°C to 15°C. The laboratory units were initially aerated; however, it was determined that complete mixing was not occurring. Mixers were then placed into the units during the subsequent tests.

Warburg respirometer studies were conducted to determine oxygen uptake rates in each laboratory aerated lagoon unit and to test for inhibitory or toxic materials. Toxicity tests were performed by measuring oxygen uptake rates at various wastewater concentrations, correcting the uptake rates by the particular dilution factor. Results of the Warburg respirometer and biological treatment studies were as follows:

1. The wastewater is non-toxic based on the Warburg respirometer studies. Sanitary wastewater organisms can become acclimated to the wastewater quite readily.

2. The wastewater already contains the necessary nitrogen and phosphorus levels to support microbial development.

3. 90 percent BOD_5 reductions are possible using a completely mixed aerated lagoon for secondary treatment. Effluent BOD_5 levels of 7 mg/l or less may be attained in such a system.

4. Secondary or final clarification is required to remove the excess microbial growth.

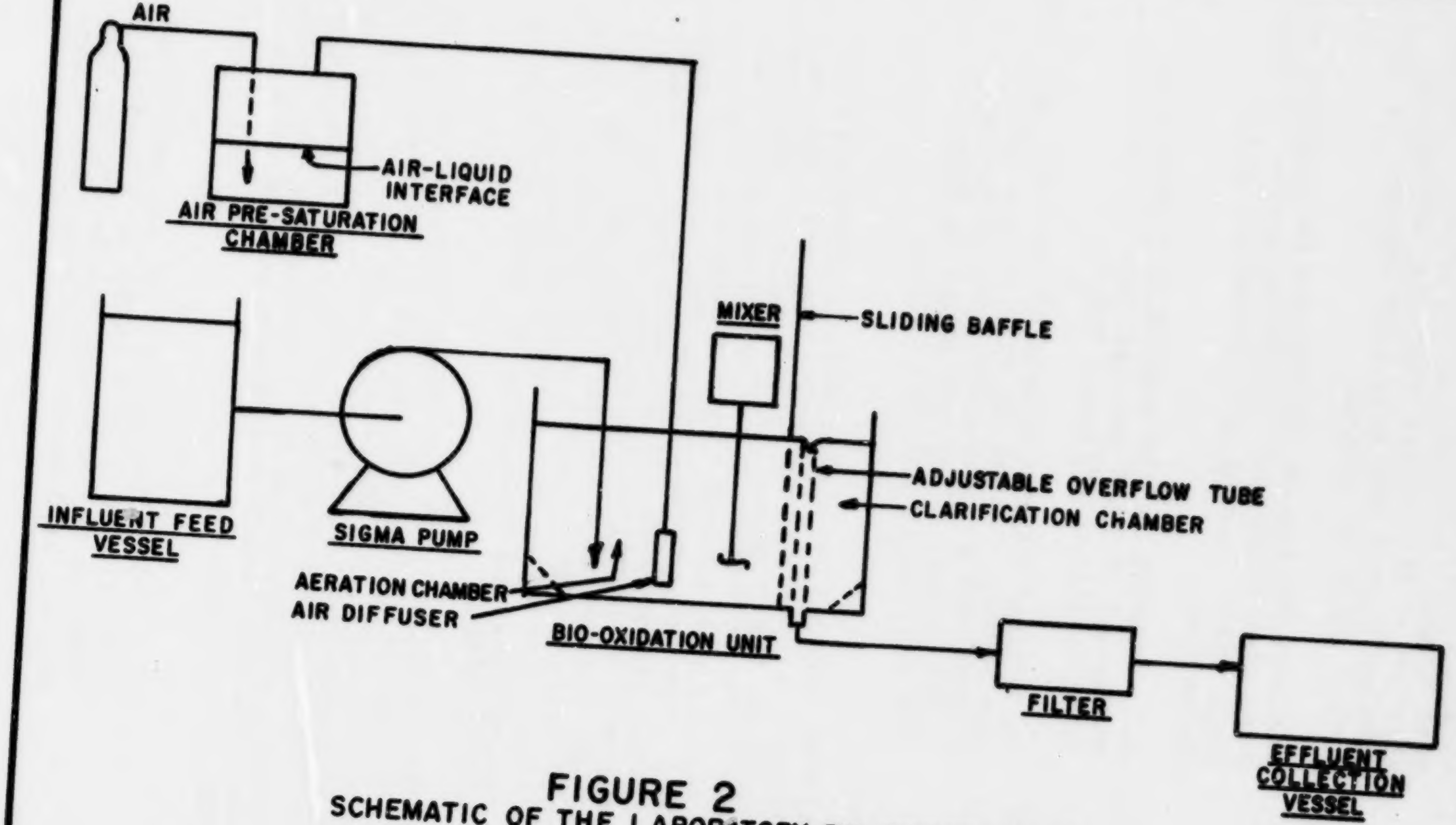
AIR
AIR-LIQUID INTERFACE
AIR PRE-SATURATION CHAMBER
MIXER
SLIDING BAFFLE
INFLUENT FEED VESSEL
SIGMA PUMP
ADJUSTABLE OVERFLOW TUBE
CLARIFICATION CHAMBER
AERATION CHAMBER
AIR DIFFUSER
BIO-OXIDATION UNIT
FILTER
EFFLUENT COLLECTION VESSEL

FIGURE 2
SCHEMATIC OF THE LABORATORY BIO-OXIDATION UNIT

5. An air flotation clarifier would provide the best method of final clarification. Settleability of the sludge from the laboratory aerated lagoon was very poor due to its dispersed phase of growth.

6. The aerated lagoon should not be operated at more than a one-day retention period to prevent under loading and consequent auto-oxidation.

7. BOD_5 loading ratios near 0.20 pounds BOD_5 per pound of MLSS per day were found to provide excellent effluent BOD_5's.

8. An average oxygen uptake of 2.6 mg/l per hour was found. Based on this oxygen uptake figure and a wastewater flow of 3.4 mgd, 1,768 pounds of oxygen would be required for the full-scale aerated lagoon.

Additional laboratory bio-oxidation tests were performed utilizing a laboratory bio-oxidation unit that was fabricated inside the plant.[8] A schematic of the laboratory unit is shown on Figure 2. The bio-oxidation unit can be used to simulate several basic biological treatment processes. Based on previous work, the unit was operated as an aerated lagoon with the influent feed rate adjusted to provide a 24-hour retention period. The influent wastewater was treated with 100 mg/l alum and 1 mg/l anionic polyelectrolyte and filtered prior to conducting the tests. Initially, wastewater was mixed with some of the laboratory's seeded BOD_5 dilution water and aerated to permit acclimation.

The bio-oxidation unit was then started up by partially filling the unit with the acclimated wastewater. The unit was operated for two days before beginning the studies. The bio-oxidation tests were run at laboratory temperatures near 25°C. Tests were run on samples taken from the influent, effluent, and the aeration chamber. Conclusions from these additional bio-oxidation studies were as follows:

1. BOD_5 reductions of near 90 percent were accomplished with a three to five-fold increase in suspended solids during biological oxidation. The MLSS levels were

difficult to determine since the biological floc formed during the tests adhered quite readily to the bottom and sides of the bio-oxidation unit.

2. MLSS levels of 60 to 150 mg/l would be expected in the full-scale aerated lagoon.

3. A BOD_5 loading ratio near 0.5 lb BOD_5 per lb MLSS per day was found during the lab tests, differing considerably from the lower loading ratio of 0.2 lb BOD_5 per lb MLSS per day previously reported. The non-agreement was due to the difference in the MLSS levels within the aeration chamber.

PILOT AIR FLOTATION TESTS

A pilot air flotation unit was rented from one of the major manufacturers of this equipment for development of design data for the full-size air flotation unit. The company's nonconventional air flotation pilot unit, incorporating a baffled flotation compartment, was selected for study because of its relatively wide loading range capabilities. Earlier laboratory tests suggested that the float stability could become a problem if the float was not removed within a short period of time, depending primarily on the wastewater's carbon black concentration and the chemical floc characteristics.

The pilot unit was operated over a three-month period to determine such design and operational information as:

1. Optimum wastewater loading rate and effective range of operation.

2. Optimum recycle rate and pressure.

3. Optimum air-to-solids ratio.

4. Suspended solids removal efficiency.

5. BOD_5, COD, and turbidity reductions during air flotation clarification.

6. Volume and concentration of sludge removed during air flotation. Sludge accumulation in bottom of air flotation unit.

Operational data from the pilot air flotation test are presented in Table 1.

DESCRIPTION OF THE PILOT AIR FLOTATION EQUIPMENT

The pilot air flotation equipment consisted of chemical feed pumps, recycle pressurization system, and a pilot air flotation unit. The pilot air flotation unit as set up during the test period is shown in Figure A-1 (Page 96). Figure A-2 (Page 96) shows the pressurization system and the chemical feed pumps. The pilot air flotation unit was a section from a full-scale unit, having a 10-square-foot flotation area and designed for an average flow rate of 50 gpm. Since the pilot unit was a section from a full-scale unit, hydraulic conditions remained constant regardless of clarifier width, enabling direct scale-up to a full-size unit from the pilot data.

The coagulation and flocculation vessels, shown schematically in Figure 3, were supplied by Firestone. The coagulation vessel was equipped with an air driven mixer with a marine-type impeller to minimize shear during alum coagulation. The vessel size permitted a 25-minute retention time during normal raw wastewater feed rates (37.5 gpm). The flocculation tank provided a five-minute retention period. Flow within the flocculation vessel provided sufficient mixing for efficient flocculation.

PILOT AIR FLOTATION TESTING PROCEDURES

Alum was used as the primary coagulant with Betz Poly-Floc 1110 used as the flocculant aid. The alum was diluted from a 50 percent solution by weight to a 10 percent solution before being fed. The flocculant aid, an anionic polyelectrolyte, was dissolved and diluted to a .066 percent solution by weight before being charged. Normal alum dosages of 65 to 100 mg/l and flocculant aid dosages of 0.5 to 1.0 mg/l were required during the pilot flotation tests. Pump settings versus chemical charge rate curves were constructed for the pilot unit's chemical feed pumps. The curves were then used to set chemical feed rates during the pilot tests.

Feed to the pilot unit was from a 100 gpm centrifugal pump drawing suction from the inlet end of the existing final settling basin. Flow was measured by an orifice plate installed in the inlet header line and recorded on a mercury type flow recorder. Recycle rates were determined by measuring the time required to fill a five-gallon container and

TABLE 1

PILOT AIR FLOTATION PERFORMANCE DATA

	Influent Characteristics				Effluent Characteristics					Sludge		Reduction	
Test No	Total Solid mg/1	Vol TS mg/1	Susp Solid mg/1	Turbidity APHA	Total Solid mg/1	Vol TS mg/1	Susp Solid mg/1	Turbidity APHA	pH Unit	Total Solid %	Vol TS %	Susp Solid %	Turbidity %
1	1876	276	100	83	1872	224	14	17	7.9	2.26	1.23	86.0	79.5
2	3436	408	194	75	3424	300	5	25	7.5	2.96	1.27	97.4	66.7
3	2940	268	94	194	3035	308	17	34	7.5	1.51	.66	81.9	82.5
4	3060	340	620	102	3136	292	36	23	7.5	5.54	1.94	94.2	77.4
5	3040	272	664	146	2736	272	28	20	8.3	5.80	1.71	95.8	86.3
6	2492	84	222	96	2216	64	32	43	8.3	5.95	3.33	85.6	55.2
7	3284	152	121	140	3092	80	54	12	8.1	5.21	3.12	55.4	91.4
8	3220	140	117	86	2964	92	8	10	7.8	4.05	2.00	93.2	88.4
9	2956	12	113	112	2664	72	14	21	8.1	1.47	.68	87.6	81.2
10	3268	40	116	116	3144	20	12	12	8.0	7.43	2.44	89.6	90.0
11	3948	344	245	105	3724	36	48	20	7.8	5.60	2.11	80.4	80.9
12	4760	440	190	120	4092	436	54	30	7.8	3.05	1.00	71.6	75.0
13	2860	416	238	170	2816	20	10	24	7.9	4.52	1.86	95.8	85.9
14	2312	344	132	136	2386	272	49	52	7.6	2.22	1.00	62.9	61.8
Avg	3104	253	226	120	2950	178	27	24	7.9	4.11	1.74	88.0	80.0
Avg*	-	-	242*	-	-	-	21*	-	-	-	-	91.3*	-

Note:* Test Nos 7, 11, and 14 not included in average. (50% Rec, 7.0 Load Rate, 3.0 Load Rate)

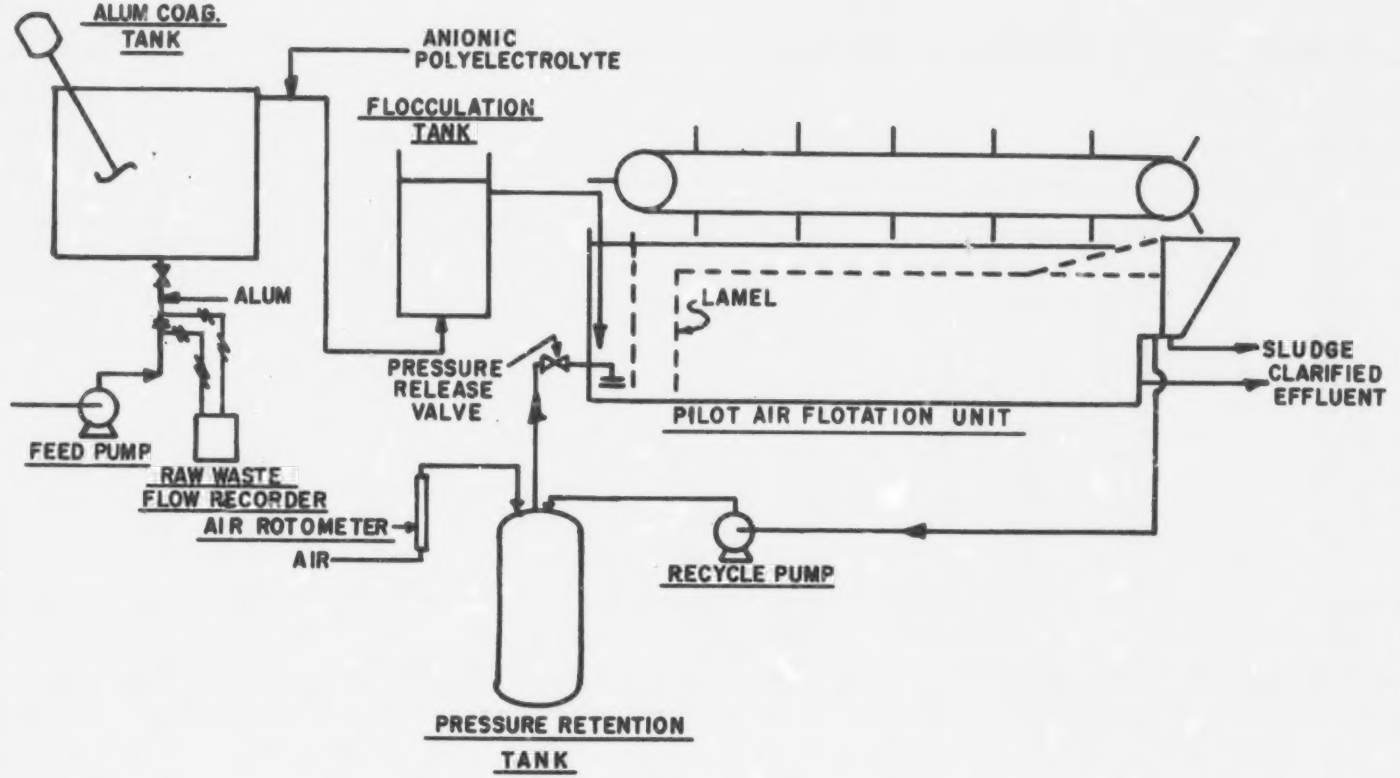
ALUM COAG. TANK
ANIONIC POLYELECTROLYTE
FLOCCULATION TANK
ALUM
LAMEL
PRESSURE RELEASE VALVE
SLUDGE
CLARIFIED EFFLUENT
PILOT AIR FLOTATION UNIT
FEED PUMP
RAW WASTE FLOW RECORDER
AIR ROTOMETER
AIR
RECYCLE PUMP
PRESSURE RETENTION TANK

FIGURE 3

SCHEMATIC OF PILOT AIR FLOTATION UNIT

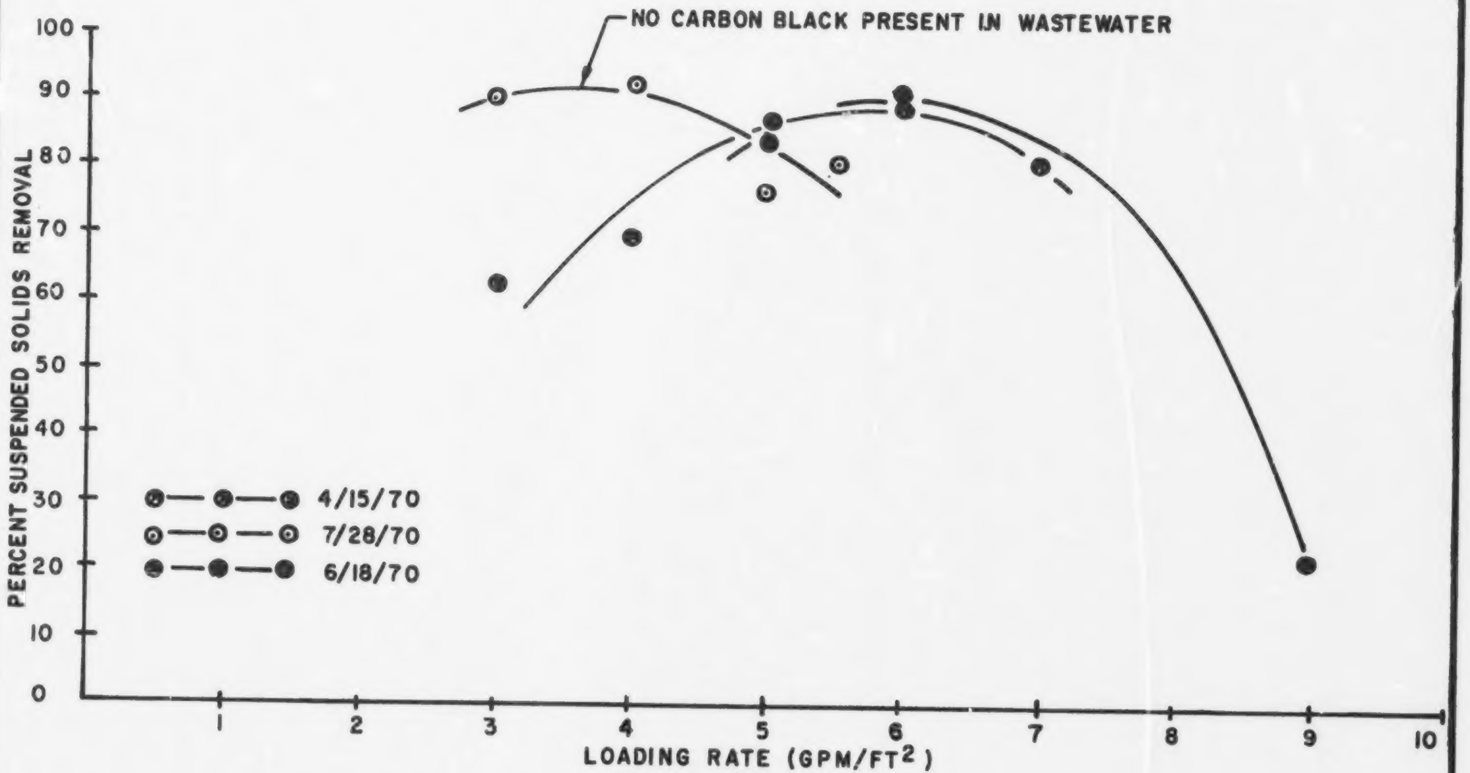

FIGURE 4

PERCENT SUSPENDED SOLIDS REMOVAL VS. LOADING RATE FOR PERMUTIT PILOT CLARIFIER adjusted accordingly. Sludge volumes were determined in a similar manner.

LOADING RATE DETERMINATIONS

The effect of carbon black in the influent to the pilot air flotation unit was clearly demonstrated during the loading rate tests, as shown in Figure 4. An optimum loading rate of 6.0 gpm/sq ft was found with carbon black present in the wastewater, while a loading rate near 4.0 gpm/sq ft was optimum during very low carbon black influent periods. The later tests indicated the necessity of being able to operate the primary air flotation unit within a 4.0 to 6.0 gpm/sq ft loading range. During the majority of the pilot studies, the pilot unit was operated at a 5.0 gpm/sq ft loading rate, with carbon black normally being present in the wastewater.

RECYCLE RATE AND PRESSURE DETERMINATION

Recycle rates of 13.6 percent to 50 percent were evaluated during the pilot tests, with rates near 20 percent providing the best degree of clarification. Turbulence became evident in the flotation unit at about 33 1/3 percent recycle, especially near the inlet of the flotation compartment. The turbulence resulted in higher suspended solids levels in the effluent from the pilot unit.

Figure 5 illustrates the importance of maintaining the wastewater pH above 6.5 pH after chemical treatment. As can be seen from Figure 5, the overall suspended solids removal efficiency was severely affected when the pH of the wastewater was allowed to fall below the 6.5 pH level after chemical treatment.

AIR-TO-SOLIDS RATIO DETERMINATION

An optimum air-to-solids ratio was not determined during the pilot work. The influent suspended solids content varied markedly, as shown in Table 1, making the latter determination difficult, if not impossible. Air was introduced to the pressure retention tank at a constant rate of 0.1 SCFM and in excess of the amount needed for recycle saturation. Based on the average suspended solids level during the pilot work and a 5.0 gpm/sq ft loading rate with 33-1/3 percent recycle, an average air/solids ratio of 0.114 lb air/lb solids was run during the pilot trials.

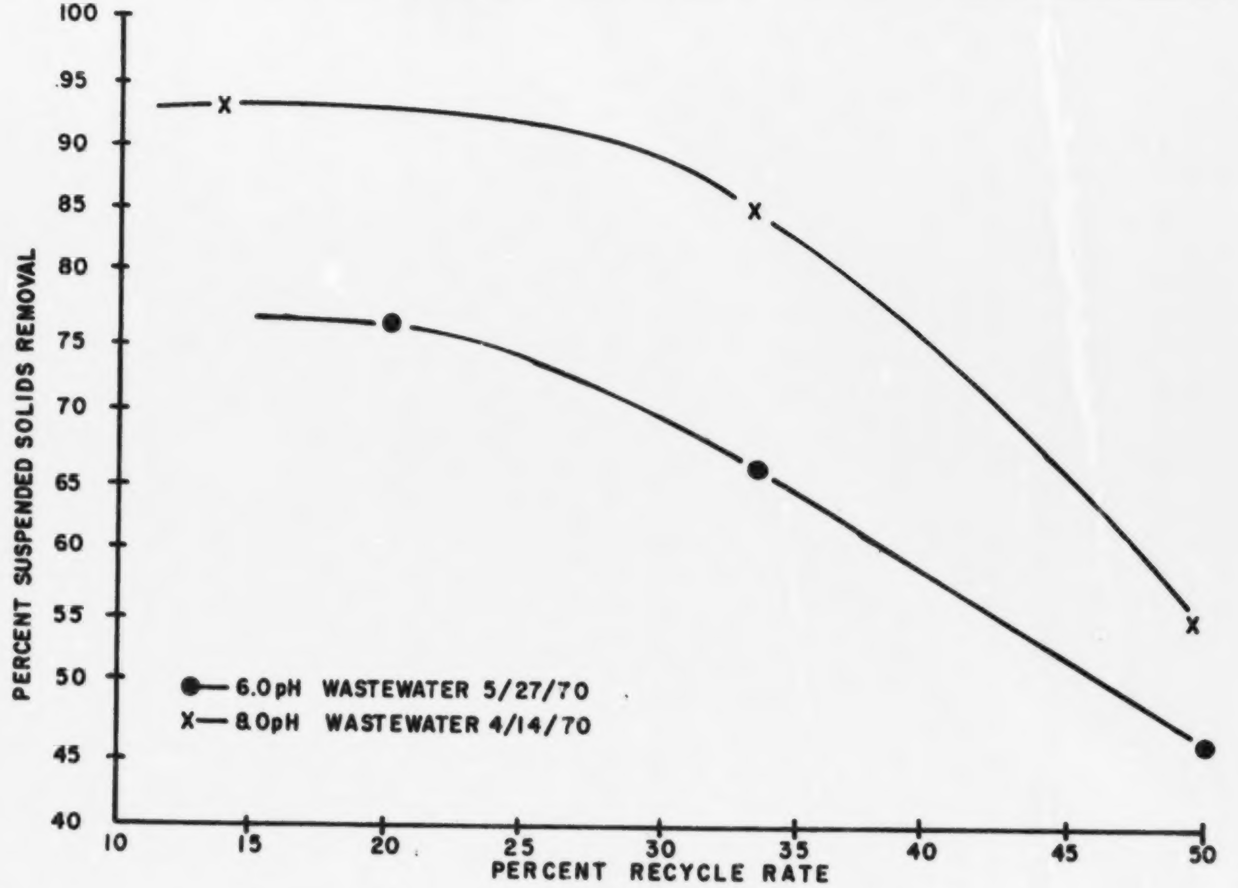

FIGURE 5
PERCENT SUSPENDED SOLIDS REMOVAL VS. PERCENT RECYCLE RATE
FOR PILOT AIR FLOTATION CLARIFIER

SUSPENDED SOLIDS REMOVAL EFFICIENCY

Suspended solids removals of near 97 percent with effluent suspended solids levels as low as 5 mg/l were attained during the pilot tests. The average suspended solids removal rate was 91.3 percent, with an effluent suspended solids concentration of 21 mg/l. The latter figures considered all the tests with the exception of those outside the 4 to 6 gpm/sq ft loading rate and above the 33-1/3 percent recycle rate.

BOD_5, COD, AND TURBIDITY REDUCTIONS

An average BOD_5 reduction of 19.8 percent was accomplished during the pilot studies. BOD_5 determinations were made on composite influent and effluent samples from the pilot unit during three different days of operation. Influent BOD_5 averaged 58.0 with an average effluent BOD_5 of 46.5. During the latter evaluations, an average COD reduction of 52.0 percent was accomplished. Turbidity reductions averaging 80 percent were observed during the pilot tests, as shown in Table 1.

SLUDGE VOLUMES CONCENTRATION AND ACCUMULATION

Sludge rates were taken over a five-day period and ranged from 0.20 gpm to 0.37 gpm, averaging 0.28 gpm. The latter sludge rates were measured at a loading rate of 5.0 gpm/sq ft and a 33-1/3 percent recycle rate. During the tests, the average sludge concentration was 4.11 percent total solids by weight, and 42.3 percent volatile content based on dry solids content. Sludge total solids varied from a low of 1.47 percent to a high of 7.43 percent, as shown in Table 1.

The full-scale primary unit would be expected to generate approximately 25,375 gallons/day sludge, or 9,386 pounds dry solids/day based on the data collected during the pilot work.

Very little bottom sludge accumulation was observed in the flotation compartment of the pilot unit during the tests. Only about an inch of sediment was evident after a three to four week operational period.

The pilot air flotation studies were run on primary wastewater only, and all design and operational data pertained to the primary clarification system. No secondary treatment facilities were in operation during the pilot air flotation tests.

SLUDGE DEWATERING STUDIES

Several different sludge dewatering methods have been evaluated. Sludge from the pilot air flotation unit as well as from the full-scale clarifiers was used in the evaluations.

Sludge Drying Bed - A simulated sludge drying bed was constructed utilizing a 55-gallon drum and a screen tray. Sludge was placed on the screen and allowed to dry. Free water was allowed to drain from the bottom of the drum. Although some dewatering was accomplished, the drying bed proved to be unsuccessful due to sludge stratification upon standing and blinding of the screen after a short period of time.

Centrifugation - Centrifugation was evaluated on a laboratory basis using both high and low speed centrifuges, and at the pilot scale level using a high speed, bowl-and-dish type solids ejecting centrifuge. Although some dewatering was obtained, operational problems occurred that eliminated this method from consideration. Due to the presence of solids within the sludge that were lighter than water, effective separation could not be obtained. Also, the centrifuge was subject to plugging caused by agglomerated rubber particles.

Screening - A pilot dual-cell, rotating screen dewatering unit was evaluated. The unit was ineffective due to rapid blinding of the screen, allowing sludge to be discharged through the dewatered solids outlet. Both organic and inorganic flocculant aids were used unsuccessfully in an attempt to alleviate this problem.

Vacuum Filtration - Three methods of vacuum filtration were investigated using a rotary drum vacuum filter. First, vacuum filtration was attempted without sludge conditioning and without the use of precoat material. The filter cloth blinded almost immediately, eliminating any filtration and creating a difficult cleaning job on the filter cloth.

The pilot vacuum filter was then used in an attempt to dewater the sludge, using lime as a sludge conditioner. Filtration was accomplished but filtration rates were extremely low. See Table 2.

TABLE 2

RESULTS OF PILOT VACUUM FILTRATION TESTS*

Filtrate Rate	2.05	GPH/sq ft
Sludge Rate	19.21	lb/hr/sq ft
Solids Rate	0.761	lb/hr/sq ft
Lime Used	0.138	lb/lb dry solids
Filter Cake Produced	3.02	lb/lb dry solids
Percent Solids in Cake.	37.7	

*With sludge conditioning but without precoat.

Based on the filtration rates obtained, a total filter area of 803 square feet would be required, assuming a service factor of 75 percent for the dewatering equipment. Therefore, the advantage of continuous operation was outweighed by the disadvantages, such as the large filter size required, the hard to handle dewatered solids, high maintenance costs, high initial capital costs, and a high degree of operator attention.

Next, vacuum filtration with the use of a precoat was tried. The precoat increased filtration rates considerably. See Table 3.

TABLE 3

RESULTS OF PILOT VACUUM FILTRATION TESTS*

Filtrate Rate	6.67	GPH/sq ft
Sludge Rate	67.5	lb/hr/sq ft
Solids Rate	2.9	lb/hr/sq ft
Precoat Used	0.256	lb/lb dry solids
Filter Cake Produced	4.3	lb/lb dry solids
Percent Solids in Cake	28.8	

*With precoat but without sludge conditioning.

In addition to the good filtrate rates, this type of filtration produced a soft, but not tacky, filter cake. Also, the initial cost of the equipment is relatively low. However, this method also had some disadvantages. Precoat usage was high because of losses during filter cake removal. The service factor was low due to the time required to apply precoat material and the high degree of maintenance necessary on this type of equipment. Also, the precoat increased filtration costs and sludge disposal costs since it added to the sludge volume.

Pressure Filtration - Studies on a pilot horizontal plate and frame filter indicated that a sludge of at least 50 percent dry solids could be obtained. During the tests, a 1.5 hour filtering cycle and 225 psi terminal filtration pressure were used. The initial cost of this type of system is high. Also, it was determined that lime sludge conditioning and the use of a precoat would be necessary. However, the filter produced a relatively dry, firm filter cake that was 50-65 percent solids. Relatively large rubber particles did not present a problem. The pressure filter proved to be very reliable and consistent. Removal of the dewatered solids and cleaning of the filter plates was not a problem.

Because of these advantages as well as the low operating costs and ease of filter capacity expansion, pressure filtration was considered to have the greatest promise of operating successfully and economically of all the methods tested.

SECTION VI

TREATMENT FACILITIES

GENERAL DESCRIPTION

Figure 6 is a flow diagram of the treatment facilities. Starting at the lower left hand corner of the page, the raw wastewater flows through a mechanically cleaned bar screen for removal of large solids. The pH is adjusted as it enters the wet well sump, or surge tank, for the raw wastewater pumps.

The water is then pumped to the alum coagulation vessel where coagulation of the suspended solids takes place. Alum and cationic polyelectrolyte are added to the water within the transfer line between the pumps and the alum coagulation vessel at points as widely separated as possible. Either may be added to the water separately or both may be added simultaneously.

The alum coagulation vessel is divided into three compartments by baffles. There is a mixer in the first compartment to insure that the alum and cationic polymer are thoroughly mixed with the wastewater. The remaining two sections are quiescent, in order to allow the floc to grow.

Leaving the alum coagulation vessel, the wastewater flows through a flow measuring box into the primary flash mixing tank. Anionic polyelectrolyte is added to the wastewater at the inlet of the flash mixing tank.

The water leaves the flash mixing tank and enters the floc-former compartment of the primary air flotation unit through a 20-inch line. An inlet distribution flume distributes the water evenly across the floc-former compartment.

Figure 7 shows the layout of the primary air flotation unit. The final air flotation unit is a mirror image of the primary unit with the exception that there is no clarifier effluent recirculated to maintain a constant flow in the final unit, as is done for the primary unit.

The clarified effluent from the primary clarifier is pumped to the aerated lagoon for BOD_5 reduction by biological treatment. The effluent of the lagoon is pumped to the final clarifier flow measuring box.

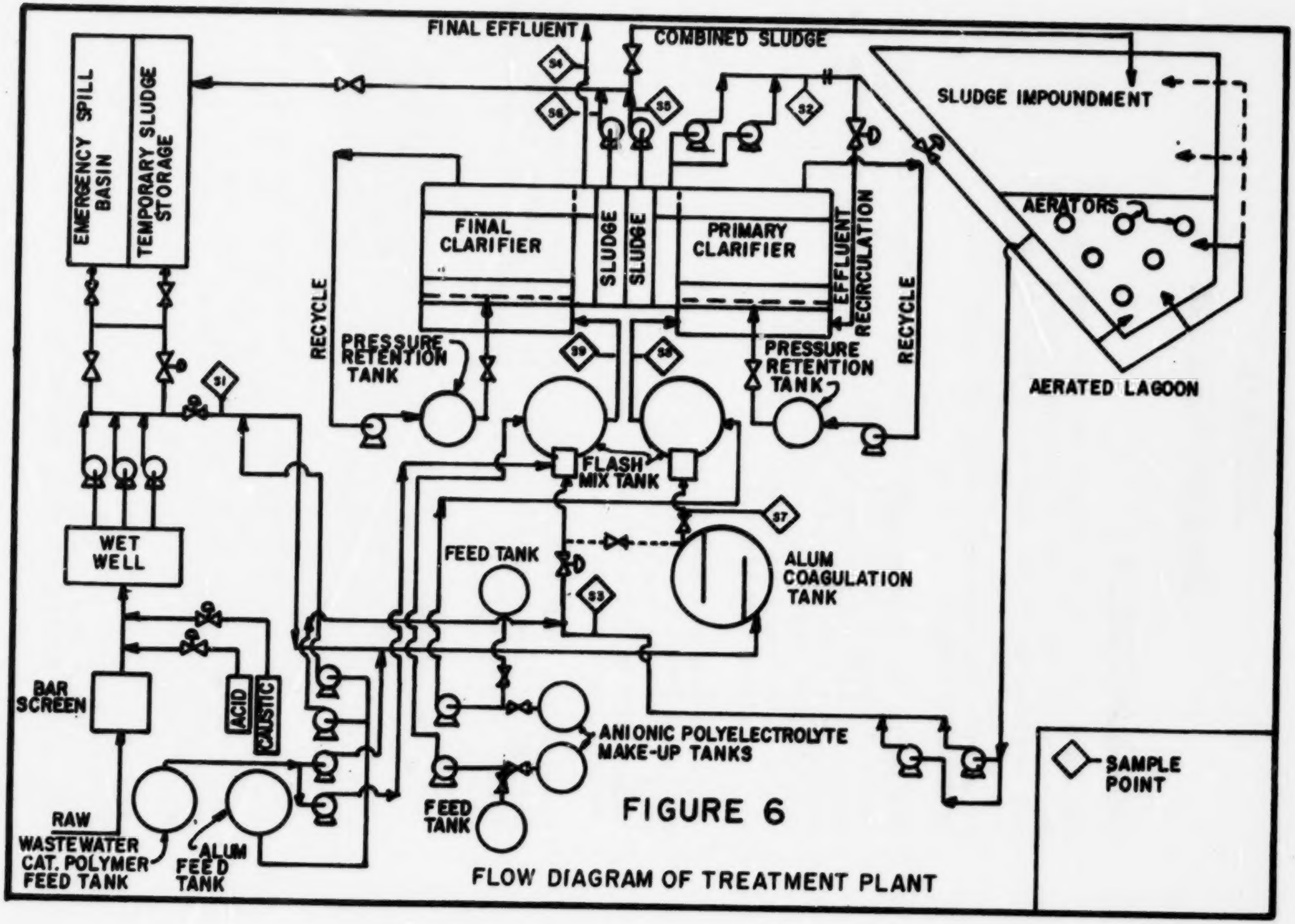
FINAL EFFLUENT
COMBINED SLUDGE
SLUDGE IMPOUNDMENT
AERATORS
AERATED LAGOON
EMERGENCY SPILL BASIN
TEMPORARY SLUDGE STORAGE
FINAL CLARIFIER
SLUDGE
SLUDGE
PRIMARY CLARIFIER
EFFLUENT RECIRCULATION
RECYCLE
RECYCLE
PRESSURE RETENTION TANK
PRESSURE RETENTION TANK
FLASH MIX TANK
FEED TANK
ALUM COAGULATION TANK
WET WELL
BAR SCREEN
ACID
CAUSTIC
RAW WASTEWATER
CAT. POLYMER FEED TANK
ALUM FEED TANK
ANIONIC POLYELECTROLYTE MAKE-UP TANKS
FEED TANK
SAMPLE POINT
S1
S2
S3
S4
S5
S6
S7
S8
S9

FIGURE 6

FLOW DIAGRAM OF TREATMENT PLANT

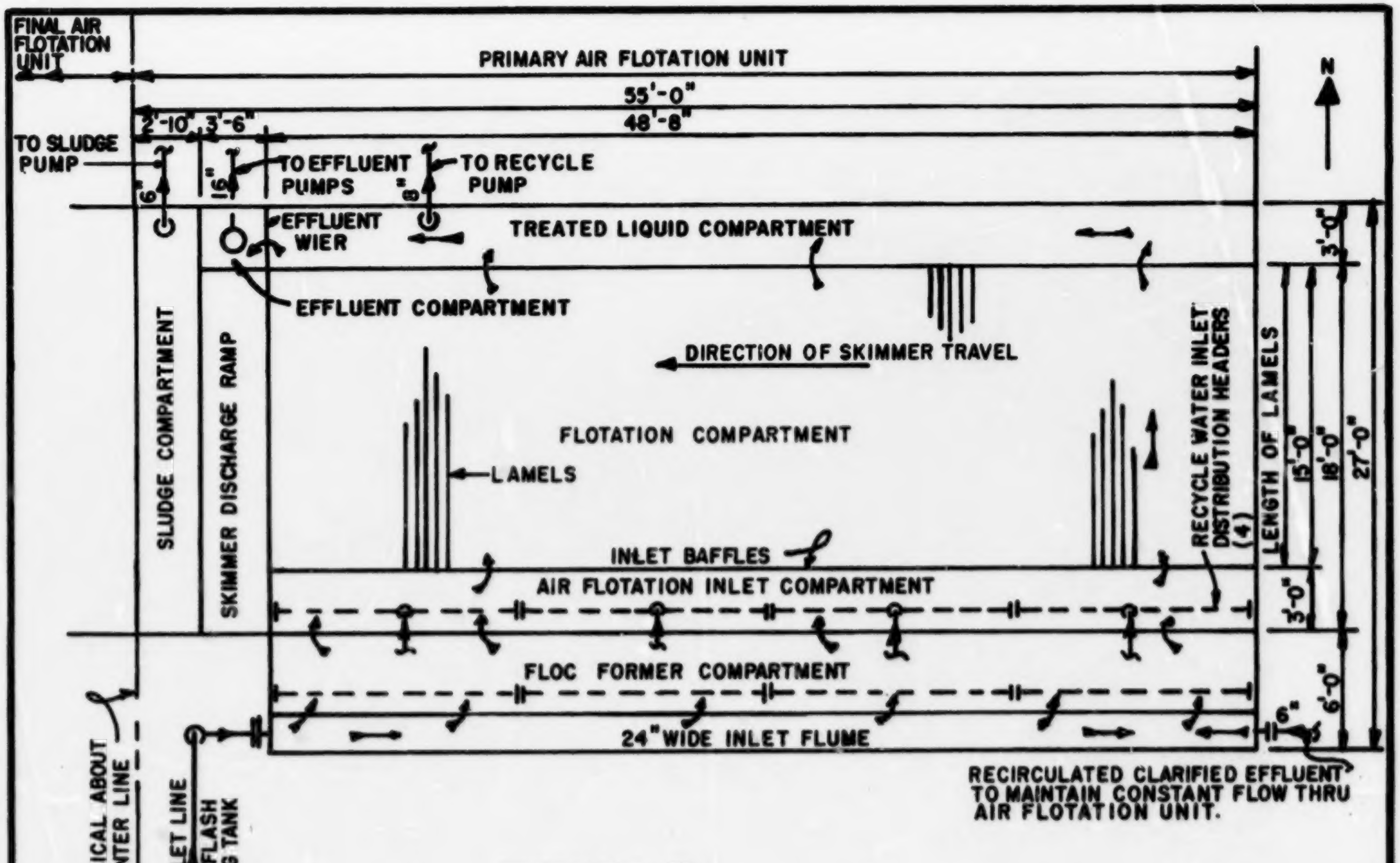
FINAL AIR FLOTATION UNIT
PRIMARY AIR FLOTATION UNIT
55'-0"
48'-8"
2'-10"
3'-6"
TO SLUDGE PUMP
6"
16"
TO EFFLUENT PUMPS
8"
TO RECYCLE PUMP
N
EFFLUENT WIER
TREATED LIQUID COMPARTMENT
EFFLUENT COMPARTMENT
DIRECTION OF SKIMMER TRAVEL
SLUDGE COMPARTMENT
SKIMMER DISCHARGE RAMP
FLOTATION COMPARTMENT
LAMELS
RECYCLE WATER INLET DISTRIBUTION HEADERS (4)
LENGTH OF LAMELS
3'-0"
15'-0"
18'-0"
27'-0"
INLET BAFFLES
AIR FLOTATION INLET COMPARTMENT
3'-0"
FLOC FORMER COMPARTMENT
6'-0"
6"
24" WIDE INLET FLUME
SYMMETRICAL ABOUT THIS CENTER LINE
24" INLET LINE FROM FLASH MIXING TANK
RECIRCULATED CLARIFIED EFFLUENT TO MAINTAIN CONSTANT FLOW THRU AIR FLOTATION UNIT.

FIGURE 7

PLAN OF PRIMARY AIR FLOTATION UNIT

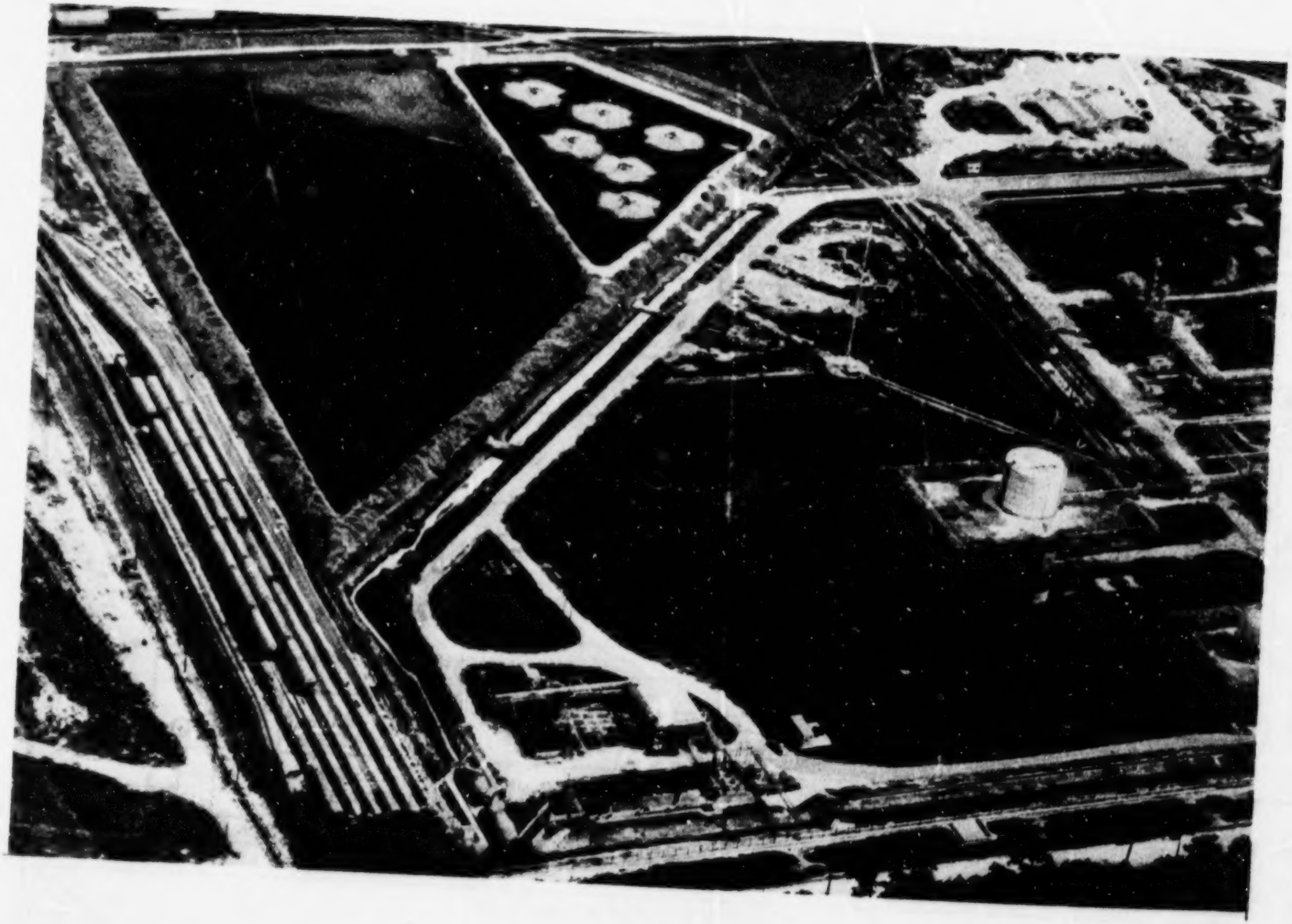

FIGURE 8

AERIAL VIEW OF WASTEWATER TREATMENT FACILITIES

Alum is added to the lagoon effluent within the transfer line. Cationic polyelectrolyte is added to the wastewater within the flow measuring box. The flow measuring box discharges into the final clarifier flash mixing tank where anionic polyelectrolyte is added.

The wastewater is transferred from the flash mixing tank to the final clarifier inlet distribution flume via a 20-inch line. The effluent from the final clarifier is discharged to a concrete-lined trench, which in turn empties into a ditch which leaves the plant property.

DESIGN CONCEPT

The treatment facilities were designed with the objective of providing the best practical treatment for the plant wastewater that would exceed any foreseeable water quality standards which might be required, and in particular, to exceed the criteria set by the Louisiana Stream Control Commission.

Since a plant expansion was in progress, it was necessary to anticipate the effect of, and to make allowances for the additional wastewater.

After a wastewater characterization study, it was decided to construct a single wastewater treatment system to treat the total plant wastewater, rather than provide separate treatment facilities for various parts of the plant. It was also decided to make every practical effort to segregate storm water from plant wastewater.

The original basic treatment scheme was similar to that shown in Figure 6, with one major exception - that approximately 45 minutes retention time be provided for equalization by utilizing the west side of the old settling basin, now held in standby for impounding spills. Existing equipment was utilized in the design and construction of the facilities whenever it was practical.

DESIGN CRITERIA

Studies indicated that chemical coagulation of suspended solids and clarification by dissolved air flotation would be required for primary treatment, that 24-hour retention with aeration and mixing would be required for secondary treatment, and that final clarification, preferably by dissolved air flotation also, would be required prior to the discharge of the wastewater.

The following table shows the pertinent parameters of the wastewater as determined for conditions before and after the proposed treatment.

TABLE 4

Pertinent Parameters

Parameter		Raw Wastewater Before Treatment		Final Discharge (Estimated)
Flow	(MGD)	2.9		3.4*
BOD_5	(lb/day)	1,707		193
	(mg/l)	71		7
Dissolved Oxygen	(mg/l)	Nil		5
Suspended Solids	(lb/day)	3,480	Less Than	283
	(mg/l)	144	Less Than	10
Oil & Grease	(lb/day)	725		0
	(mg/l)	30		0
Total Chromium	(lb/day)	2.7		0
	(mg/l)	0.11		0
Phenols	(lb/day)	7.2		0
	(mg/l)	0.30		0
Chlorides	(lb/day)	16,943	Less Than	16,943
	(mg/l)	701	Less Than	701
Sulfates as SO_4	(lb/day)	12,423		12,423
	(mg/l)	514		514

*Plant expansion in progress, which increased flow.

Extensive laboratory and pilot plant tests were conducted by plant personnel to verify the results of earlier studies and to provide additional data needed for the design of treatment equipment. From these tests it was determined that alum and anionic polyelectrolyte would definitely be required in the chemical treatment of the raw wastewater.

It was decided that existing unloading and storage facilities would be utilized for receipt of alum and that the anionic polymer would be received in the dry form and would be stored in a new building at the treating facilities. An alum serving tank with transfer facilities would be installed for the treatment system.

Due to the anticipated cost of chemicals required, it was decided that the feed of chemicals should be proportional to the effluent flow. Previously existing facilities that were incorporated into the present treatment system include the raw wastewater pump wet well and the twin settling basins.

It was decided that floating-type mechanical aerators would be used in order to allow for fluctuations in the water level in the aerated lagoon, since retention time, and consequently lagoon level, appeared to be a critical factor in BOD_5 reduction.

Preliminary specifications were drawn up by plant engineering personnel. The services of an engineering firm were then obtained for finalizing specifications and obtaining competitive quotations on the required equipment.

SECTION VII

DEMONSTRATION
SAMPLING AND TESTING

During the grant period, Firestone personnel carried out complete daily testing of plant wastewater, following a sample schedule recommended by the EPA Water Quality Office. Sample points were selected at various locations throughout the treatment system so that individual unit performance as well as overall system performance could be studied and evaluated.

SAMPLING

Locations - There were nine major sampling points. The location of each is denoted by a numbered flag in Figure 6.

Procedures - Three different sampling methods were used. A continual, automatic composite sampler was used for collecting raw wastewater, primary clarifier effluent, lagoon effluent, and final effluent (sample points 1, 2, 3, and 4). Figure 9 shows the automatic sampling system. Grab samples from sample points 7, 8, and 9 were caught every six hours and combined for a 24-hour composite sample. Grab samples from sample points 5 and 6 (primary and secondary sludge) were caught every eight hours and combined for a 24-hour composite.

Schedule - Samples were taken every day at the nine major sampling points. Table 5 shows the tests that were performed on each sample.

Automatic Composite Sampling System - The sampling system consists of four samplers for obtaining composite samples from four separate points in the wastewater treatment system: the raw wastewater, the primary clarifier effluent, the lagoon effluent, and the final clarifier effluent.

Each sampler is composed of two 3/4-inch three-way valves with pneumatic actuators. The three-way valves of each sampler are connected by a ten-inch long piece of 3/4-inch pipe, the volume of which determines the amount of the sample that is retained each time the sampler is actuated.

The sample stream flows continuously into the lower valve, up through the interconnecting pipe, and out through the

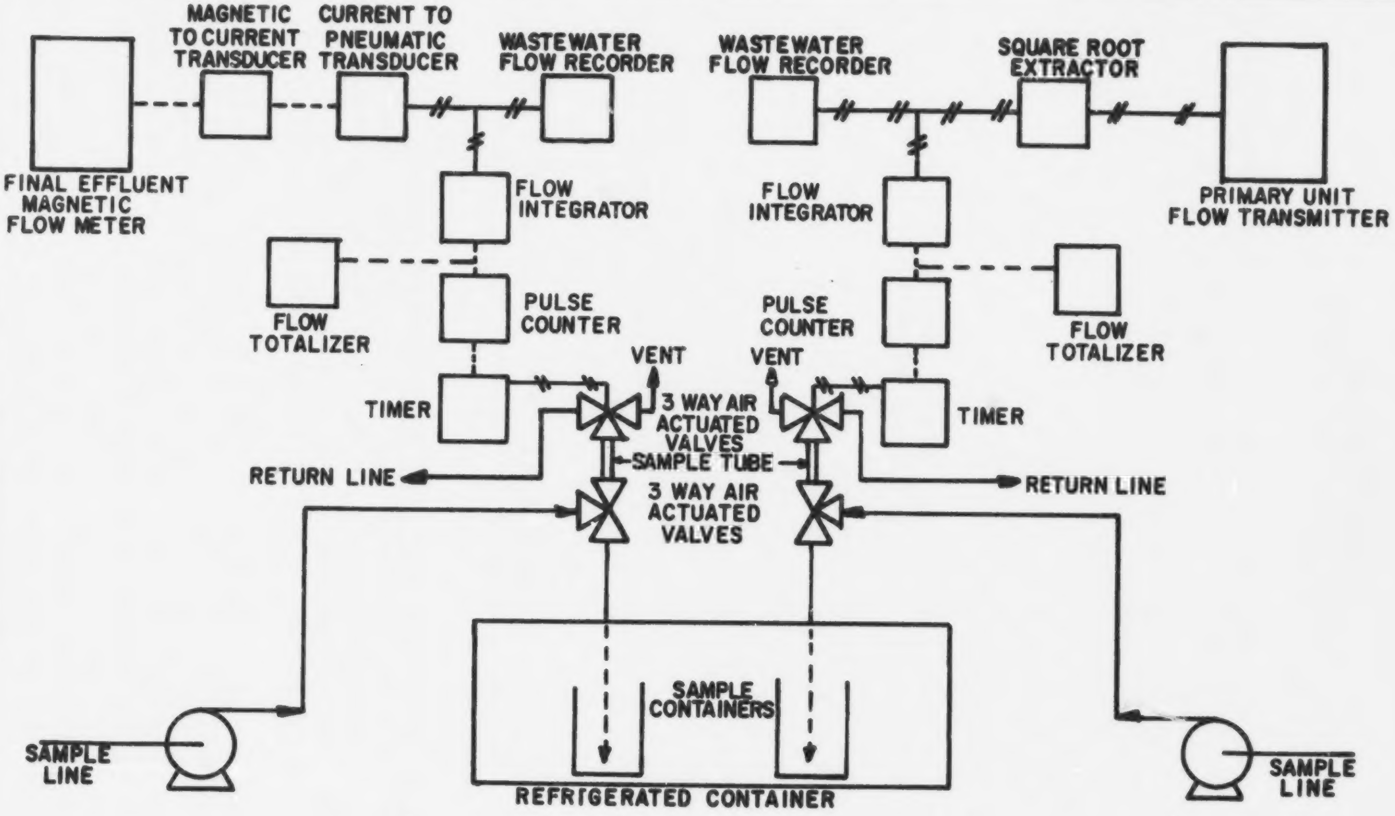
MAGNETIC TO CURRENT TRANSDUCER
CURRENT TO PNEUMATIC TRANSDUCER
WASTEWATER FLOW RECORDER
WASTEWATER FLOW RECORDER
SQUARE ROOT EXTRACTOR
FINAL EFFLUENT MAGNETIC FLOW METER
FLOW INTEGRATOR
FLOW INTEGRATOR
PRIMARY UNIT FLOW TRANSMITTER
FLOW TOTALIZER
PULSE COUNTER
PULSE COUNTER
FLOW TOTALIZER
VENT
VENT
TIMER
3 WAY AIR ACTUATED VALVES
TIMER
RETURN LINE
SAMPLE TUBE
RETURN LINE
3 WAY AIR ACTUATED VALVES
SAMPLE CONTAINERS
SAMPLE LINE
SAMPLE LINE
REFRIGERATED CONTAINER

FIGURE 9

SCHEMATIC OF WASTEWATER AUTOMATIC COMPOSITE SAMPLER

TABLE 5

WASTE SAMPLING AND TESTING SCHEDULE

	Raw Water to Bar Screen	Final Effluent to Bayou	Equalized Raw Water to Mix Tank 1	Feed to Primary Clarifier After Flash Mix Tank 1	Effluent from Primary Clarifier	Effluent from Lagoon at Pumps	Feed to Final Clarifier after Flash Mix Tank 2	Sludge from Primary Clarifier	Sludge from Final Clarifier
pH	A	A	B	B	A	A	B	B	B
Total Solids	A	A	B	B	A	A	B	B	B
Inorganic	A	A	B	B	A	A	B	B	B
Organic	A	A	B	B	A	A	B		
Susp. Solids	A	A	B	B	A	A	B		
Inorganic	A	A	B	B	A	A	B		
Organic	A	A	B	B	A	A	B		
Set. Sol.(Ml/l)	A	A	B	B	A		B		
Turb. (APHA)	A	A			A				
BOD_5	A	A			A				
COD	A	A			A				
DO	A	A			A				
TOC*	A	A							
Cr +6	A	A							
Cr +3	A	A							
SO_4	A	A							
Oil & Grease	A	A						B	B
Phenol	A	A			A				
PO_4	A	A							
Chloride	A	A							
NH_3*	A	A	B						
Nitrate N*	A	A	B						
Nitrite N*	A	A	B						
Total Carbon	A	A							

Results in mg/l except as noted.
*All tests were run daily with the following exceptions:
1. TOC & TC - 2/week
2. NH_3, Nitrite, and Nitrate - 1/week

A = 24-Hour continuous composite
B = 1 Grab/6 Hours (24-hour composite)
C = 1 Grab/8 Hours (24-hour composite)

return outlet of the upper valve while the sampler is in the de-energized position. When the sampler is energized, both valves rotate simultaneously. The return outlet of the upper valve is shut off and the interconnecting tube is opened to the vent connection. At the lower valve the sample supply is shut off and the interconnecting pipe is opened to the drain outlet of the valve. This allows the sample that is trapped between the valves to drain down into a sample container.

Although the system consists of four samplers, Figure 9 shows only two in order to simplify the diagram. In reality, the flow integrator of the primary unit flow meter actuates samplers for both the raw wastewater and the primary clarifier effluent, and the flow integrator of the final effluent flow meter actuates samplers for the lagoon effluent and the final clarifier effluent.

The output of each of the flow integrators goes to a pulse counter which provides the signal to actuate the samplers. The counter provides the actuating signal each time a predetermined quantity of water has been indicated by the flow integrator. The predetermined quantity may be changed by adjusting the dial setting of the counter,but must not be changed after the sampling period of a composite sample has begun or the integrity of the sample will suffer.

A timer determines the length of time that the samplers remain actuated. Only sufficient time must be provided to allow the sample to completely drain into the sample container.

Sample pumps have been provided for the raw waste water and final clarifier effluent samplers, since these two streams are in concrete trenches. No sampling pumps are needed for the primary clarifier effluent or the lagoon effluent since these streams are already under pressure in transfer pipe lines.

A chest type freezer was used to keep the sample containers refrigerated. The thermostat of the freezer was replaced with one of the proper range to maintain a controlled temperatue of 40° F. Holes were drilled through the back of the freezer in order to run the drain tubes from the samplers into the sample containers inside the freezer.

TESTING

Methods - All analytical testing was done in accordance with the twelfth edition of Standard Methods for the Examination of Water and Wastewater, with the following exceptions:

1. Nitrogen as ammonia - Determined by the Hach Test Kit method.

2. Nitrogen as nitrite - Determined by the Hach Test Kit method.

3. Phenols - Determined by the Hach Aminoantipyrene method.

By making determinations on standard solutions, the Hach method was found to be both accurate and reliable. However, a spectrometer was used for concentration determinations rather than the standard color wheel. A transmittance versus concentration curve was determined from standard solutions.

Outside Testing - Heavy metal tests were run on a quarterly basis as part of the routine test and analysis of the process effluent. The tests were run on 24-hour composite samples that were chemically stabilized and shipped to an outside laboratory. Table 6 summarizes the results of the tests.

PROBLEMS

Several problems were encountered in the testing procedures during the demonstration period. The TOC instrument was not received until mid-October and was not used for testing until the first of November. The high chloride content of the wastewater, an average of about 1300 mg/l, caused some difficulties. Chloride interference in the COD tests was enough to increase the test results by 10-15 percent. Nevertheless, the tests were performed in accordance with Standard Methods, which does not correct for a chloride content below 2000 mg/l. Sample turbidity caused some difficulties in determining the hexavalent chromium content. Starting the first of November, samples were prepared in a manner that reduced the turbidity problem, causing the results to be appreciably lower than the reported values for the preceding months. There was some difficulty in getting representative sludge samples. The installation of a sludge circulation system in each clarifier during March resulted in more uniform samples for laboratory analysis during the remainder of the demonstration period.

TABLE 6

METAL ANALYSIS
of
FINAL EFFLUENT

		Sample Date	
Metal	10/29/71	2/8/72	5/16/72
Antimony as Sb	ND (1000)	ND (1000)	ND (1000)
Chromium, Total as Cr	50	50	50
Cobalt as Co	100	ND (100)	ND (100)
Copper as Cu	80	ND (10)	20
Iron, Total as Fe	1500	900	2000
Lead as Pb	100	ND (100)	ND (100)
Manganese as Mn	250	250	220
Mercury as Hg	ND (0.1)	8.8	ND (0.1)
Molybdenum as Mo	1000	ND (1000)	ND (1000)
Nickel as Ni	ND (100)	200	300
Silver as Ag	10	10	ND (10)
Tin as Sn	ND (1000)	ND (1000)	ND (1000)
Zinc as Zn	160	140	300
(Additional Metals)			
Aluminum as Al	530	-	-
Barium as Ba	ND (100)	-	-
Beryllium as Be	ND (10)	-	-
Boron as B	140	-	-
Cadmium as Cd	ND (10)	-	-
Calcium as Ca (ppm)	32	-	-

*Results reported in ppb unless otherwise noted.
ND - Not detected below indicated concentration.

SECTION VIII

TREATMENT PLANT PERFORMANCE

OPERATIONAL DATA

Wastewater Flow Data - Raw and final wastewater flow data during the demonstration period are presented in Table 7 below.

TABLE 7

WASTEWATER FLOW RATES

	Raw Wastewater				Final Effluent			
	High*	Low*	Average**		High*	Low*	Average**	
Date	gpm	gpm	gpm	mgd	gpm	gpm	gpm	mgd
Oct.71	2831	2231	2388	3.43	2814	2109	2551	3.67
Nov.	3030	2044	2562	3.69	3019	2456	2620	3.77
Dec.	3423	2156	2734	3.94	2966	2344	2823	4.06
Jan.72	3473	1935	2613	3.76	3079	2228	2614	3.76
Feb.	2696	1553	1993	2.87	2869	836	2175	3.13
March	2696	1692	2159	3.11	2914	2025	2486	3.58
April	2745	1635	2117	3.05	2925	1800	2369	3.41
May	2576	1642	2150	3.10	2741	1676	2343	3.37
June	2840	1897	2182	3.14	2891	800	2180	3.14
Average			2322	3.34			2462	3.55

*Daily average data
**Monthly average of daily data

Very little wastewater flow equalization is built into the primary wastewater treatment system. Adequate flow stabilization, however, is provided by the aerated lagoon during secondary treatment.

Segregation of the process wastewater and storm waters after completion of the effluent collection and distribution system has provided even less flow equalization than existed before the effluent and storm sewers were combined.

The primary air flotation clarifier was sized such that during normal raw wastewater flow rates, approximately 20 percent of the clarified effluent is recirculated back through the unit to maintain optimum clarifier loading conditions. The primary clarifier's flow recirculation system has helped to maintain a fairly constant flow rate within the unit. During very high wastewater flow periods, no means of regulating flow is provided and clarifier performance is affected.

Chemical Feed Rates - Chemical feed rate data for the Primary and Secondary Clarification Units are presented in the following Table 8.

TABLE 8

CHEMICAL FEED RATES*

	Primary Clarification			Secondary Clarification		
Month	Alum	Cat. Polymer	Anionic Polymer	Alum	Cat. Polymer	Anionic Polymer
Oct. 71	20	4.6	.79	58	3.8	.82
Nov.	44	2.6	.76	36	2.4	.75
Dec.	62	1.5	.85	58	1.8	.89
Jan. 72	52	0.0	.63	57	0.0	.62
Feb.	20	2.8	.73	33	4.7	.61
March	40	5.4	.70	29	4.8	.57
April	37	4.7	.70	27	3.8	.53
May	29	3.6	.61	24	3.2	.49
June	30	3.6	.70	34	3.1	.53
Average	37	3.2	.72	40	3.1	.65

*Data represent daily average concentrations as mg/l based on total wastewater flow.

Turbulence within the chemical treatment units, especially in the primary treatment unit, resulted in higher chemical requirements than experienced during earlier jar tests. Use of the cationic polyelectrolyte in conjunction with alum improved clarification efficiencies by producing a chemical floc that was tougher than the fragile alum floc; however, turbulence was still a problem.

The earlier jar tests ran on effluent from the laboratory aerated lagoon indicated that an anionic flocculant aid alone would bring about effective flocculation. However, the water in these laboratory tests did not contain the carbon black present in the effluent from the full-scale aerated lagoon. A cationic coagulant was required during the full scale evaluations due to the presence of carbon black and also to the biological sludge's dispersed nature and apparent charge neutrality. The carbon black concentration in the lagoon effluent steadily decreased during the nine-month demonstration period. The alum and flocculant aid requirements consequently also decreased during the same period.

Clarifier Downtime - Table 9 was compiled to show downtime on the air flotation clarifiers during the demonstration period.

TABLE 9

DOWNTIME ON AIR FLOTATION CLARIFIERS

	Primary Clarifier			Secondary Clarifier		
Date	Total DT (Hrs)	DT for Cleaning (Hrs)	% DT for Cleaning	Total DT (Hrs)	DT for Cleaning (Hrs)	% DT for Cleaning
Oct. 71	10.50	8.50	80.9	17.33	8.67	50.0
Nov.	0.00	0.00	0.0	12.50	0.00	0.0
Dec.	169.50	83.50	49.3	117.75	0.00	0.0
Jan.72	123.50	0.00	0.0	23.92	0.00	0.0
Feb.	11.25	11.25	100.0	59.33	13.00	21.9
March	7.75	7.75	100.0	3.92	0.00	0.0
April	0.00	0.00	0.0	11.25	10.33	91.8
May	0.00	0.00	0.0	4.75	0.00	0.0
June	18.25	18.25	100.0	16.00	0.00	0.0

1. Total downtime over the 9-month period was 5.2% of total possible operating time.

2. Total downtime over the 9-month period was 4.1% of total possible operating time.

Downtime figures have been reported for both the "primary" and "secondary" clarifier; however, in examining the results tabulated above, the following discussion should be considered.

Firestone's wastewater treatment system was designed to insure that a primary air flotation clarifier would be in operation 100 percent of the time. The dissolved air flotation units are interconnected to permit use of the "secondary" clarifier as the primary clarifier when necessary.

During periods of downtime on the secondary clarifier, the aerated lagoon will "normally" contain enough surge capacity to absorb the wastewater discharge until the secondary unit can be returned to service.

Primary clarifier downtime during the nine-month demonstration period was 340.75 hours, which represented 5.2 percent of the total possible operating time. The primary unit was shut down six times during the demonstration period for cleaning, resulting in 129.25 hours downtime, or 37.9 percent of the total downtime. The cleaning downtime figure was abnormally high for the number of cleanings. Maintenance requirements during some of the cleanings resulted in extended downtime.

The bulk of the solids removed from the bottom of the primary clarifier during cleaning was solids that were rich in carbon black having a relatively high specific gravity.

Secondary clarifier downtime during the demonstration period was 266.75 hours, or 4.1 percent of the possible 6,552 hours operating time. The secondary unit was shut down three times for cleaning during the nine-month period. Cleaning of the final clarifier accounted for 32 hours, or 12.0 percent of the total downtime.

Both air flotation units incorporate bottom sludge blowdown headers, located inside sludge collection troughs, that tie into the suction line of the clarifier sludge pump. The sludge collection trough runs the width of the flotation compartment near the outlet and beneath the float removal ramp. The floor of the clarifier is sloped towards the outlet end and into the sludge collection trough. The clarifiers, after a period of time, require a shutdown to remove the settled solids.

During normal operation the sludge is routinely drawn off the bottom of the clarifier; however, due to the nature of the sludge, not all of it will migrate to the sludge collection trough. Cleaning of a clarifier normally requires a 6 to 10-hour period using a firehose to flush the solids into the sludge collection troughs. The sludge pump is left operating during the water-flushing operation until all the sludge is pumped from the unit.

Wastewater Characteristics - Influent-Effluent data collected during the demonstration period are shown in Table 11. The data represent the average of all the daily test results run on 24-hour continuous composite samples made up of 6-hour grab samples. Primary and aerated lagoon effluent characteristics are shown in Table 13. The data represent the average of all the daily test results run on 24-hour continuous composite samples.

Monthly Percent Removal Data - Monthly performance data are shown in Tables 14 and 15 for the more pertinent wastewater parameters.

Sludge Characteristics - Primary and secondary sludge characteristics are shown in Table 10 below. Tests were run on 24-hour composite samples composed of 8-hour grab samples.

TABLE 10

SLUDGE CHARACTERISTICS

(All Data)

Sludge Parameter*	Primary Sludge				Secondary Sludge			
	Avg.	High	Low	Std. Dev.	Avg.	High	Low	Std. Dev.
Total Solids	7.80	19.63	.62	3.48	5.75	18.08	1.24	2.31
Inorganic Solids	3.20	15.62	.46	1.78	3.12	7.14	.40	1.08
Organic Solids	4.63	16.20	.16	2.69	2.64	13.30	.40	1.61
Oil & Grease	1.67	8.90	.05	1.45	.66	9.76	.01	1.04

*Data as weight %

During the first five months of the demonstration period, an outside firm was contracted to remove and dispose of the

TABLE 11

INFLUENT - EFFLUENT CHARACTERISTICS
(All Data)

Wastewater Parameter*	Raw Wastewater Average	Raw Wastewater High	Raw Wastewater Low	Raw Wastewater Std. Dev.	Final Effluent Average	Final Effluent High	Final Effluent Low	Final Effluent Std. Dev.
pH (Unit)	7.7	12.3	2.5	0.9	7.3	10.6	5.8	0.6
Total Solids	3443	7715	1130	865	3220	5496	2004	618
Inorganic Solids	3179	5552	930	820	3101	5144	1935	611
Organic Solids	266	2340	45	193	120	472	24	53
Suspended Solids	197	1074	28	127	29	243	0	24
Suspended Inorg. Solids	78	427	0	65	10	161	0	17
Suspended Org. Solids	118	800	7	88	20	82	0	13
Settleable Solids (ml/l)	6.2	100.0	.1	14.8	.39	7.00	0.00	.80
Turbidity (APHA)	70	496	3	66	14	77	3	10
BOD_5	72.1	334.6	31.9	39.4	11.5	51.3	1.9	10.4
COD	447	2167	92	257	73	201	8	31
DO	4.1	7.9	.0	1.6	7.5	10.0	1.4	1.2
Total Carbon	86	166	52	18	42	68	19	10
TOC	63	131	33	18	25	43	8	8
Chromium (+6)	.023	1.050	.000	.080	.005	.165	.000	.014
Chromium (+3)	.181	1.500	.000	.179	.044	.375	.000	.046
SO_4	714	3800	250	262	734	1560	440	117
Oil & Grease	40.9	1026.0	2.0	71.3	7.2	99.8	.1	9.1
Phenol	.199	.980	.010	.148	.048	.400	.000	.053
PO_4	40	85	0	11	28	51	0	11
Chloride	1158	2603	324	406	1141	2334	471	335
NH_3 (N)	3.5	8.5	1.0	2.0	2.8	9.5	.4	2.0
Nitrate (N)	.78	3.88	.08	.60	.43	1.19	.03	.24
Nitrite (N)	.72	2.19	.00	.51	.77	1.80	.20	.34

*Results in mg/l unless noted.

TABLE 12

WASTEWATER CHARACTERISTICS AFTER CHEMICAL TREATMENT

Wastewater Parameter	Equalized Raw Water to Mix Tank No 1			Feed to Primary Clarifier After Mix Tank No.1			Feed to Secondary Clarifier After Mix Tank No.2		
	Average	High	Low	Average	High	Low	Average	High	Low
pH (Unit)	7.3	10.3	6.3	7.3	11.5	6.2	7.2	10.2	6.0
Total Solids	3412	7116	1284	3394	6692	1544	3274	4980	2080
Inorganic Solids	3144	6852	1144	3101	6328	1156	3098	4752	1990
Organic Solids	268	1095	50	243	1120	35	177	945	20
Suspended Solids	271	975	44	189	759	22	129	451	30
Suspended Inorganic Solids	121	706	10	77	342	2	64	254	7
Suspended Organic Solids	150	730	19	112	621	2	65	435	6
Settleable Solids, ml/1	15.3	125.0	.1	7.8	100.0	0.1	7.1	32.0	0.3
NH_3 (N)	2.9	8.5	.9	-	-	-	-	-	-
Nitrate (N)	.64	5.10	.04	-	-	-	-	-	-
Nitrite (N)	.73	3.18	.12	-	-	-	-	-	-

Results in mg/l unless noted.

TABLE 13

PRIMARY CLARIFIER EFFLUENT - AERATED LAGOON EFFLUENT CHARACTERISTICS (ALL DATA)

Wastewater Parameter*	Primary Clarifier Effluent				Aerated Lagoon Effluent			
	Average	High	Low	Std. Dev.	Average	High	Low	Std. Dev.
pH (Unit)	7.4	12.2	2.8	.9	7.4	10.5	3.7	.7
Total Solids	3308	10304	1540	918	3370	5895	2175	663
Inorganic Solids	3090	7356	1212	790	3191	5475	2028	633
Organic Solids	152	2948	0	186	180	904	30	106
Suspended Solids	52	282	2	43	124	650	25	79
Suspended Inorg. Solids	22	178	0	29	62	371	0	54
Suspended Org. Solids	31	163	0	21	62	298	2	33
Settleable Solids (ml/l)	2.8	60.0	0	8.7	-	-	-	-
Turbidity (APHA)	22	85	5	17	-	-	-	-
BOD_5	51.1	116.8	20.8	19.1	-	-	-	-
COD	162	553	50	64	-	-	-	-
DO	4.6	8.2	0	1.5	-	-	-	-
Phenol	176	980	000	127	-	-	-	-

*Results in mg/l unless noted.

TABLE 14

MONTHLY SUSPENDED SOLIDS REMOVAL DATA

Month	Primary Clarifier			Secondary Clarifier			Overall		
	Infl.	Eff.	% Rem.	Infl.	Eff.	% Rem.	Raw	Final	% Rem.
October 1971	283	49	82.7	191	33	82.7	283	33	88.3
November	206	45	78.2	142	19	86.6	183	19	89.6
December	236	35	85.2	180	44	75.6	202	44	78.2
January 1972	175	31	82.3	114	27	76.3	172	27	84.3
February	192	70	63.5	135	21	84.4	276	21	92.4
March	214	50	76.6	114	28	75.4	164	28	82.9
April	158	42	73.4	134	25	81.3	162	25	84.6
May	122	52	57.4	86	28	67.4	117	28	76.1
June	208	93	55.3	128	37	71.1	204	37	81.9
Average	199	52	73.9	136	29	78.7	196	29	85.2

All test results as mg/l

TABLE 15

MONTHLY PERFORMANCE DATA - NINE MONTHS DEMONSTRATION PERIOD

Month	B O D			C O D			T O C		
	Raw	Final	% Rem.	Raw	Final	% Rem.	Raw	Final	% Rem.
October 71	84.5	13.8	83.7	561	80	85.7	-	-	-
November	88.1	11.1	87.4	653	71	89.1	65	21	67.7
December	75.9	20.9	72.5	539	101	81.3	56	26	53.6
January 72	64.0	20.2	68.4	451	94	79.2	68	26	61.8
February	88.1	10.2	88.4	460	70	84.8	81	27	66.7
March	70.5	7.3	89.6	430	67	84.4	57	23	59.6
April	47.6	5.1	89.3	314	54	82.8	54	20	63.0
May	56.7	7.1	87.5	275	64	76.7	64	29	54.7
June	68.3	6.1	91.1	339	58	82.9	68	21	67.2
Average	71.5	11.3	84.2	447	73	83.7	64	24	62.5

	Oil and Grease			Phenol			Total Chromium		
	Raw	Final	% Rem.	Raw	Final	% Rem.	Raw	Final	% Rem.
October 71	53.2	7.8	85.3	.435	.066	84.8	.271	.077	71.6
November	36.6	6.7	81.7	.281	.051	81.9	.091	.025	72.5
December	43.1	7.8	81.9	.190	.087	54.2	.142	.047	66.9
January 72	86.8	13.0	85.0	.167	.072	56.3	.166	.031	81.3
February	35.0	6.1	82.6	.123	.031	74.8	.214	.050	76.6
March	31.2	6.3	79.8	.100	.028	72.0	.195	.044	77.4
April	24.8	5.7	77.0	.093	.031	66.7	.226	.053	76.5
May	21.5	5.5	74.4	.159	.032	79.9	.222	.039	82.4
June	27.2	5.4	80.1	.177	.042	76.3	.257	.069	73.2
Average	39.9	7.1	82.2	.192	.049	74.5	.198	.048	75.8

*All test results as mg/l

plant's combined sludge. During this period the combined sludge volume averaged 22,500 gpd. Sludge total solids averaged 5.6%, yielding 11,340 lb/day of dry solids.

On-site lagooning of the sludge was begun on March 16, 1971. Both primary and secondary sludge were pumped directly from the air flotation clarifier to the sludge impounding lagoon. Plans are to utilize the sludge impounding lagoon for sludge disposal until a satisfactory means of dewatering and/or disposal can be found.

Recycle Rate, Loading Rate, and Air-To-Solid Ratio - Recycle rates between 22 and 30 percent proved to be the optimum operating range for both air flotation clarifiers. Recycle rate variations around the primary clarifier during normal operations did not affect solids removal efficiencies to any great extent. Recycle rate adjustments were made only during extended high or low raw wastewater flow periods. However, varying the recycle rate across the secondary air flotation clarifier produced a greater effect on solids removal. Recycle rates below or above the 20 to 30 percent range resulted in rapid decreases in suspended solids removal across the secondary unit, especially during the earlier operational period when carbon black levels were relatively high in the lagoon effluent. For this reason, recycle adjustments were recommended on the unit whenever flow rates were varied.

Loading rates near 5.5 gpm/sq ft were found to be optimum for the primary clarifier, with loading rates near 4.2 gpm/sq ft being optimum for the secondary clarifier. Primary effluent clarity begins to drop sharply below loading rates near 4.5 gpm/sq ft. The secondary clarifier's performance was found to be relatively stable between 3.5 to 5.0 gpm/sq ft loading rates.

Air-to-solids ratio determinations were performed only on the secondary air flotation clarifier. Air-to-solids ratios near 0.1 lb air/lb solids provided the best clarification. Higher air-to-solid ratios resulted in poorer solids removal with those above 0.3 lb air/lb solids showing visual turbulence (due to excess free air) in the air flotation compartment near the recycle release headers. Flow and solids variation around the primary air flotation unit made it difficult to accurately determine an optimum air-to-solids ratio and impossible to control at a set ratio during operation.

PROCESS DESIGN CRITERIA FROM OPERATIONAL DATA

Air Flotation - Air-to-solids ratios of near 0.06 lb air/lb solid provided effective solids removal across the primary clarifier; whereas, secondary air-to-solid ratios near 0.1 lb air/lb solid produced the best clarification.

Oxygen and air solubility curves are shown in Figures 10 and 11 for the plant's combined wastewater. During the solubility determinations, a permeable membrane dissolved oxygen meter and a constant temperature water bath were used in developing the data. Dissolved oxygen measurements were performed on distilled water as an experimental control during the tests. The distilled water control agreed fairly well with handbook data. From the oxygen solubility data, a curve was constructed for the plant wastewater over the normal wastewater temperature range.

Figures 12 and 13 are included to show the relationship between percent solids removal and influent suspended solids levels during actual operation. Data for the curves were taken from the May through June, 1972 period of operation. The curves suggest that percent suspended solids removal across an air flotation unit alone is not necessarily a measure of system performance, as indicated by the curve's scattered points. Many other variables affect the performance of an air flotation system, as discussed in the theoretical section of this report, and must be taken into account before drawing any definite conclusions concerning operational variables.

Biological Oxidation - Monthly BOD_5 loading rates are shown in Table 16.

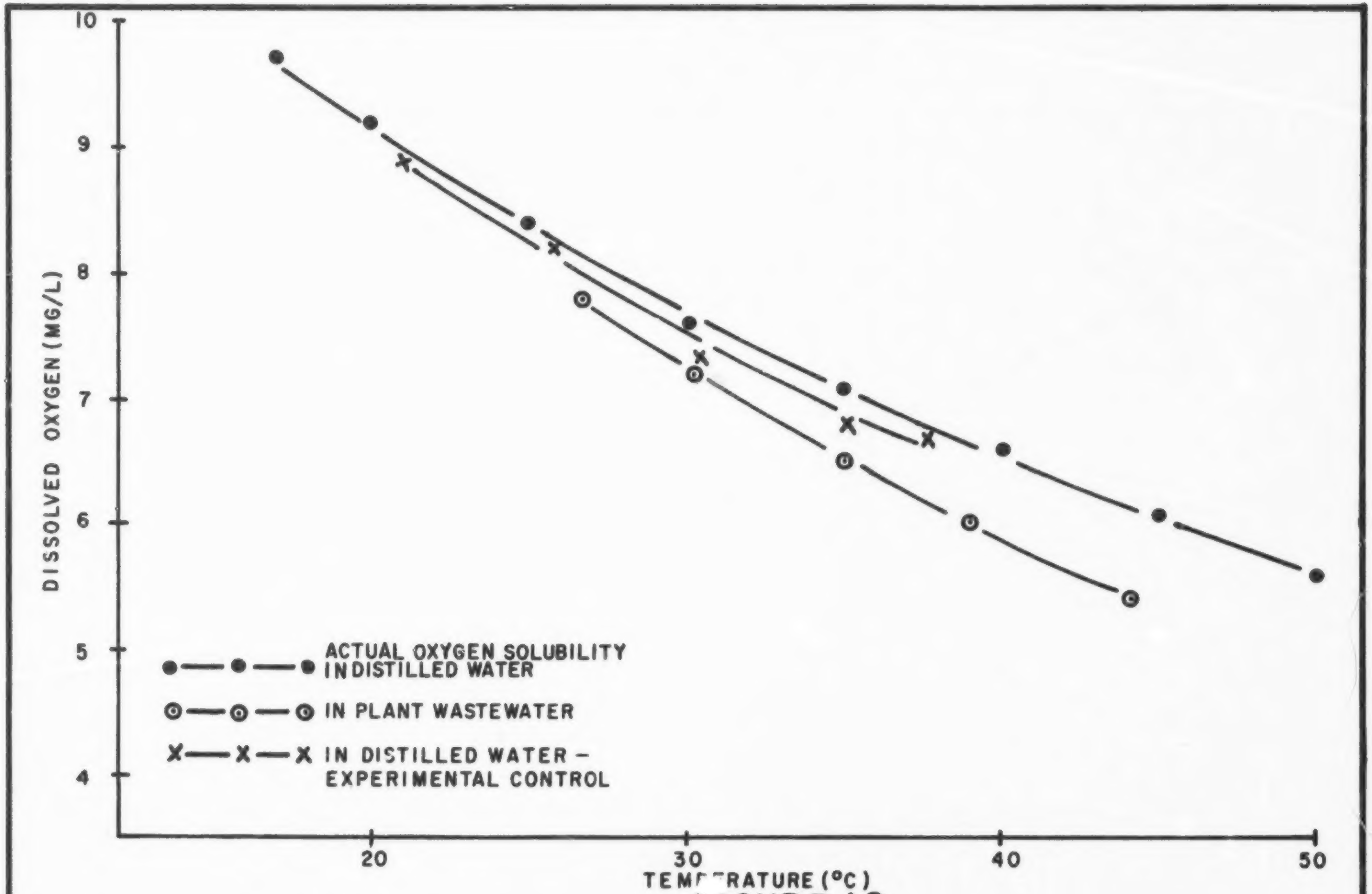

FIGURE 10
SOLUBILITY OF OXYGEN IN PLANT WASTEWATER VS. TEMPERATURE

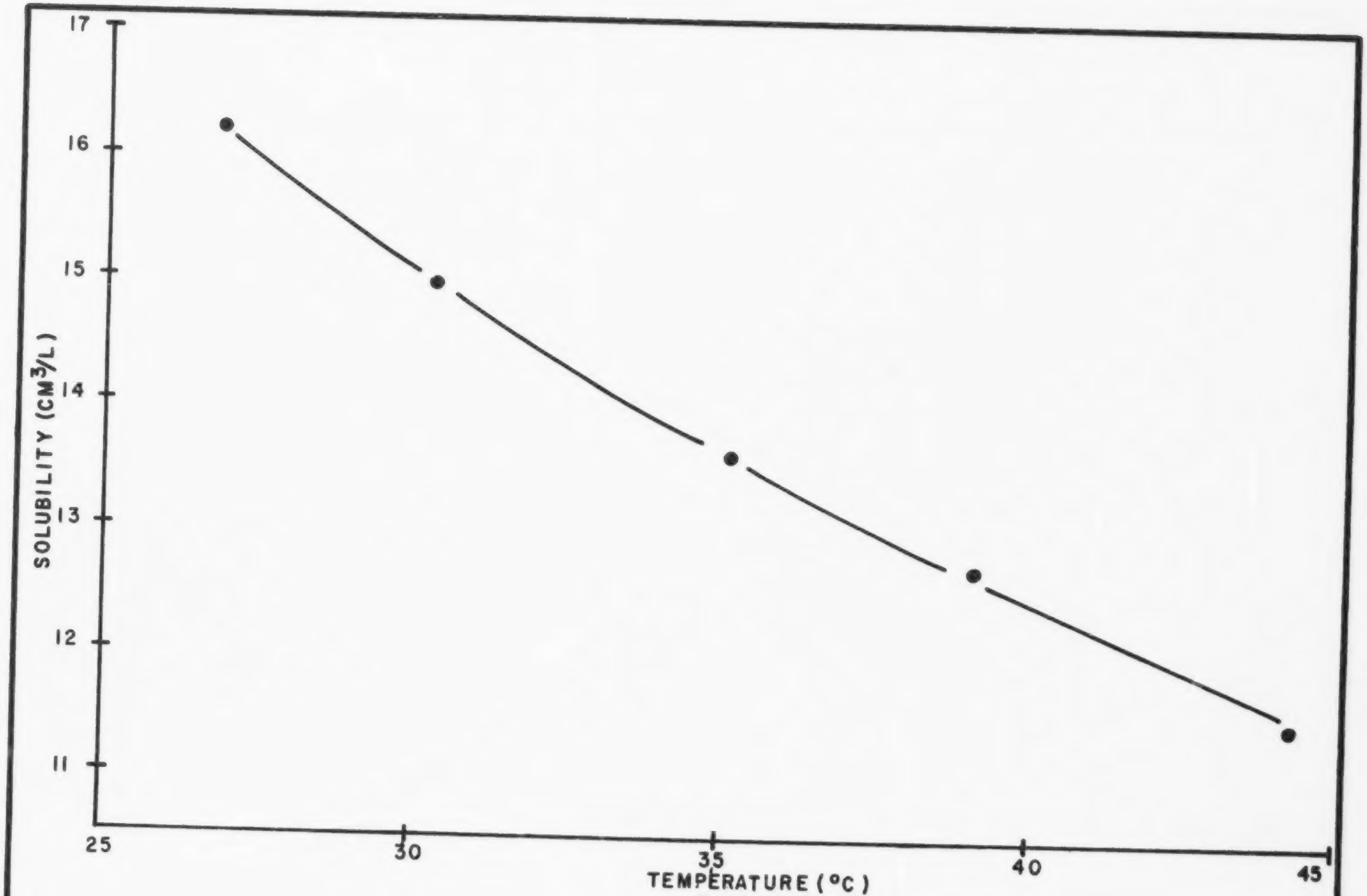

FIGURE II

SOLUBILITY OF AIR IN PLANT EFFLUENT VS. TEMPERATURE

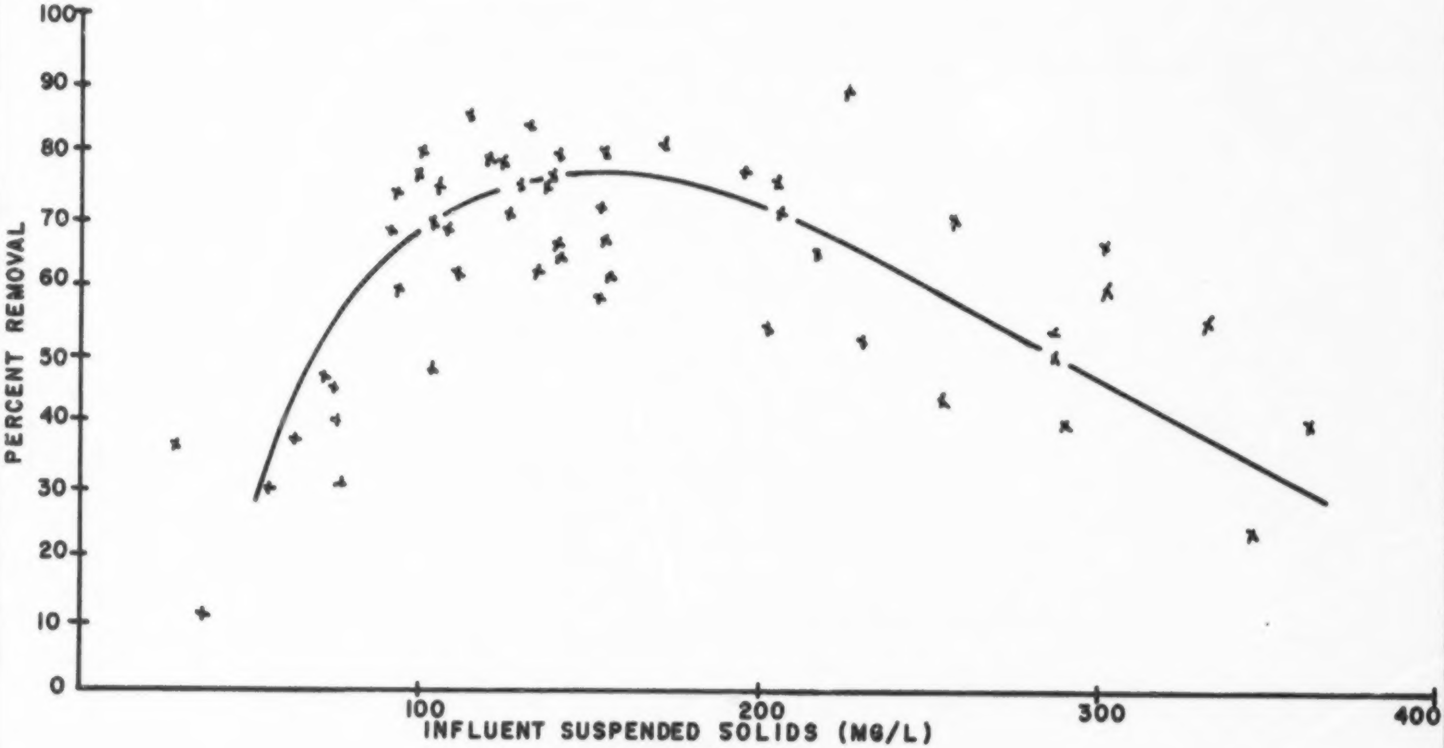

FIGURE 12

PERCENT REMOVAL VS. INFLUENT SUSPENDED SOLIDS FOR PRIMARY CLARIFIER DURING MAY AND JUNE, 1972

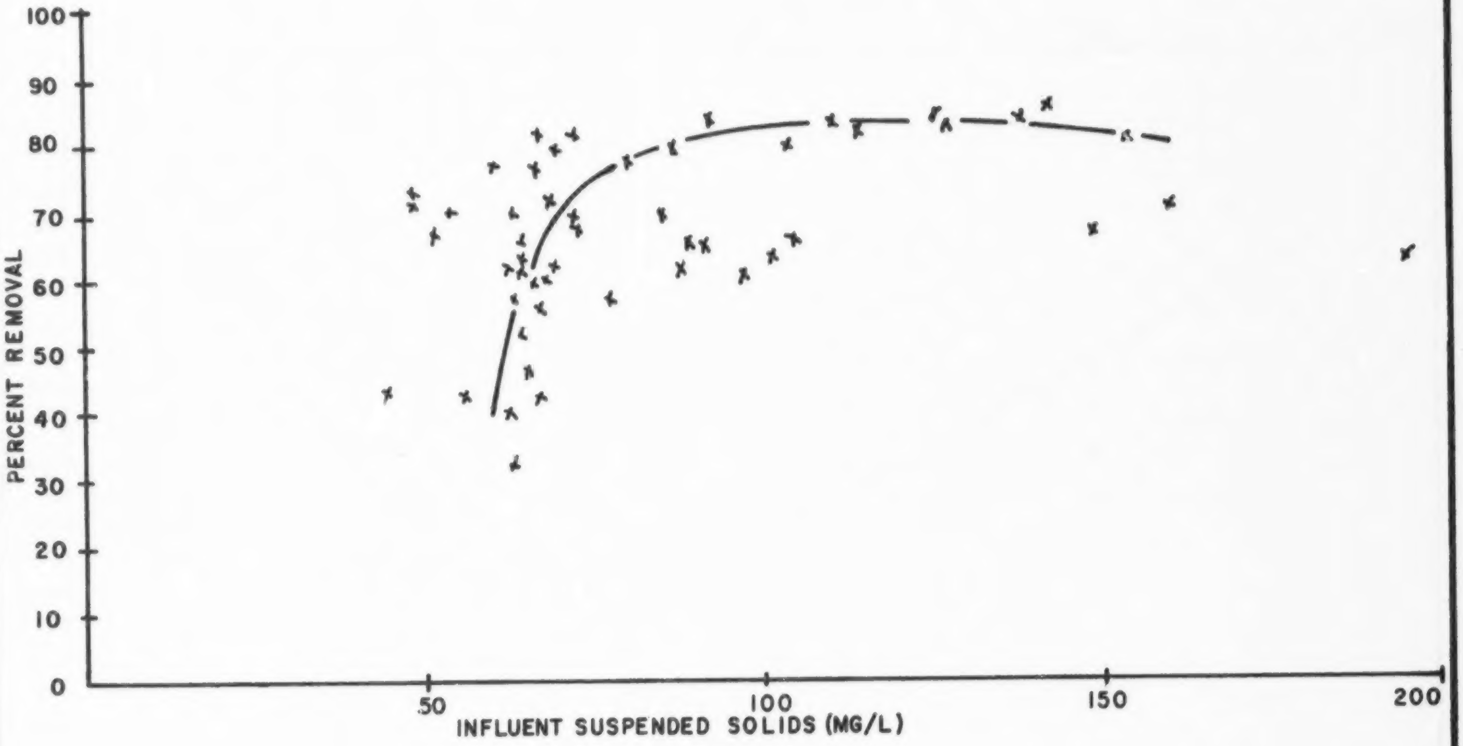

FIGURE 13

PERCENT REMOVAL VS. INFLUENT SUSPENDED SOLIDS FOR SECONDARY CLARIFIER DURING MAY AND JUNE, 1972

TABLE 16

MONTHLY BOD_5 LOADING RATES FOR AERATED LAGOON

Month	Influent BOD (mg/l)	Lagoon MLSS (mg/l)	Retention Time(Days)	BOD Loading mg/l BOD/day mg/l MLSS
Oct. 71	59.8	191	0.625	0.501
Nov.	65.0	140	0.625	0.743
Dec.	55.5	136	0.375	1.088
Jan. 72	52.8	117	0.375	1.203
Feb.	60.9	166	1.000	0.367
March	48.7	101	1.000	0.482
April	42.7	80	1.000	0.534
May	50.2	75	1.000	0.669
June	44.6	119	1.000	0.375
Average 9 Months	53.4	125	0.78	0.548
Average Mar.-June '72	46.6	94	1.000	0.496

An average monthly BOD_5 loading of .548 lbs BOD_5/day/lbs MLSS was found during the demonstration period. The latter loading rate was considerably higher than those found during the initial laboratory studies, the difference being in the MLSS concentration that was maintained in the aeration basin. Laboratory bio-oxidation tests by plant personnel agreed very well with the actual BOD_5 loadings found during the nine-month study period.

Figure 14 is a curve showing the relationship between effluent BOD_5 and the BOD_5 loading rate. The latter curve suggests non-linearity below a BOD_5 loading rate of around 0.48 mg/l BOD_5/day/mg/l MLSS with a minimal attainable average effluent BOD_5 of near 4 mg/l at the low substrate concentrations. (The last four months of the demonstration period were used for curve construction to better represent normal lagoon performance.)

Figure 15, relating BOD_5 removal to BOD_5 loading, is presented to show the average BOD_5 removal efficiency during the March through June period of operation. A relatively constant BOD_5 removal efficiency of 86.2 percent was demonstrated during this period.

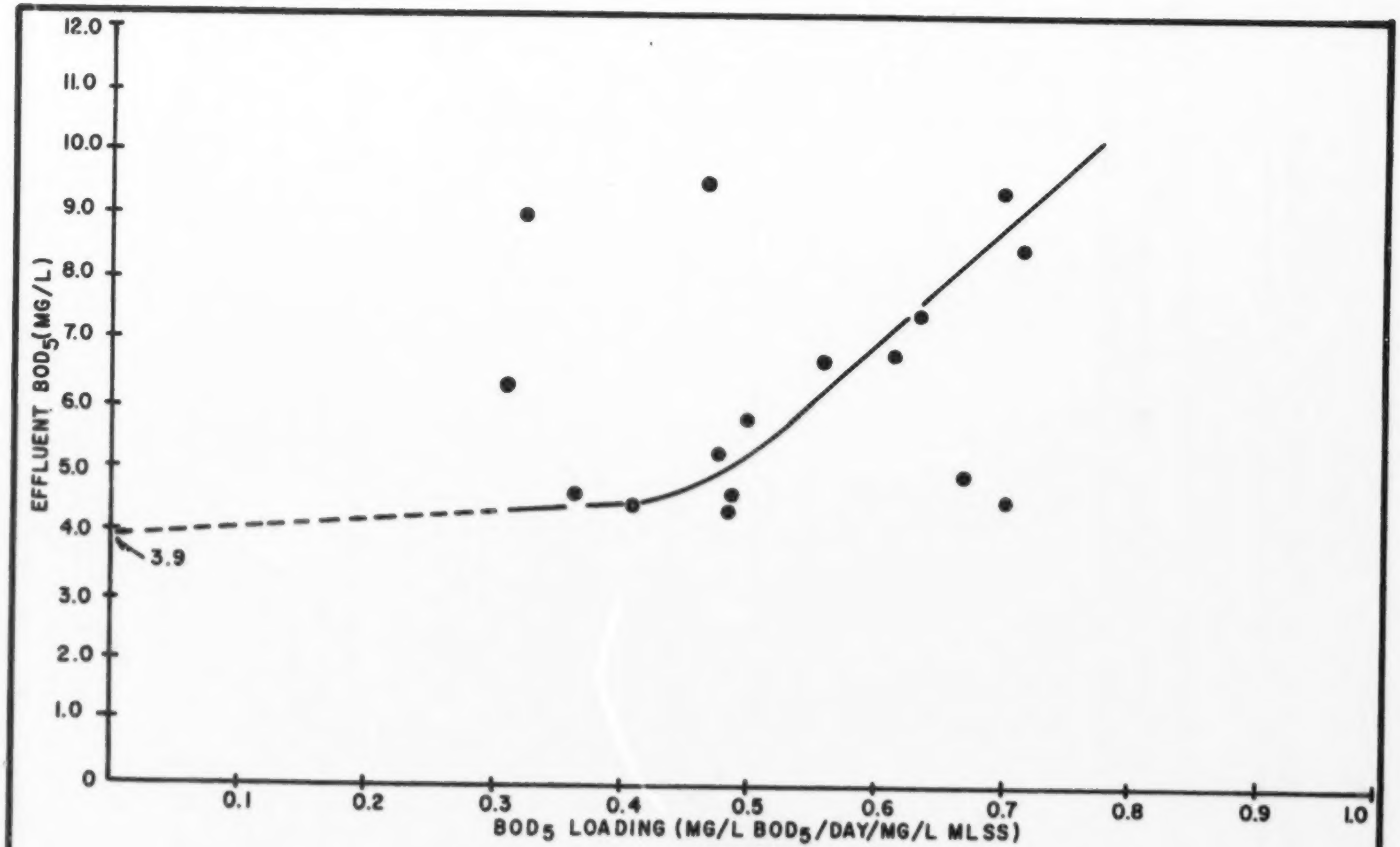

FIGURE 14

EFFLUENT BOD$_5$ VS. BOD$_5$ LOADING FOR AERATED LAGOON
WEEKLY AVERAGES FOR MARCH - JUNE, 1972

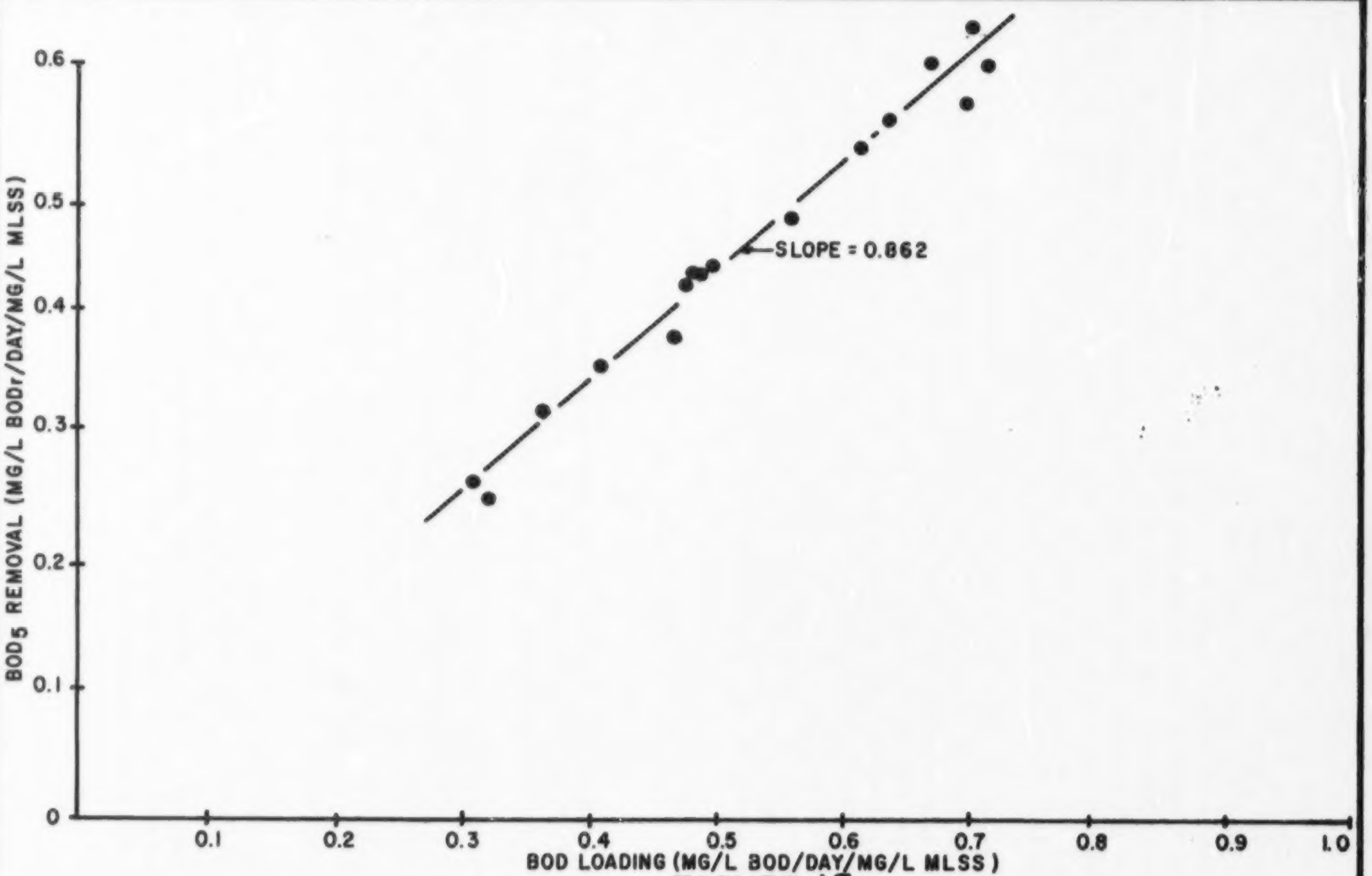

FIGURE 15

BOD_5 REMOVAL VS. BOD_5 LOADING FOR AERATED LAGOON
WEEKLY AVERAGES FOR MARCH-JUNE, 1972

Monthly substrate removal rate coefficients are shown in Table 17 for the nine-months' demonstration period. An average substrate removal rate coefficient (k) of .0023 l/mg-hr (or .055 l/mg-day) was found during the nine-month period. An average (k) .0028 l/mg-hr (or .067 l/mg-day) was shown for the last four months of the demonstration period. BOD_5 removal rate versus effluent BOD_5 curves is shown in Figure 16 using average weekly data during March through June, 1971. The slope of Curve A represents the average BOD_5 removal rate coefficient as determined graphically, while Curve B was drawn to depict (k) as the mathematical average of all the data considered during the latter period of operation.

Figure 17 was constructed using bi-weekly data averages from March through June, 1972, for graphical determinations of the biological oxidation constants, "a" and "b". The slope of the sludge yield versus BOD_5 removal rate curve represented an average cell yield coefficient (a) of .447 mg/l VSSp/mg/l BOD_5 removal for the biological treatment system. The "Y" intercept of the latter curve represents an average endogenous respiration constant (b) of .084 day^{-1}. Using the sludge yield equation presented in Section V, equation (13) becomes:

$$Xv = S_o + .447\ Sr - .084\ S_v \qquad (13\text{-}1)$$

The above equation does not describe the sludge yield for the first five months of the demonstration period for reasons presented in the following discussion.

The aerated lagoon after its initial construction was used as a sedimentation pond prior to installation of the effluent collection and distribution system. The effluent from the plant's carbon black masterbatch units was diverted into the lagoon before being allowed to enter the final settling basin. (Presently the emergency spill and temporary sludge storage basins.)

Bio-oxidation studies indicated that the smaller lagoon contained the necessary volume required for effective biological oxidation of the plant's combined wastewater. Economic considerations therefore dictated that the small lagoon be utilized as the aerated lagoon in the wastewater treatment scheme.

TABLE 17

BOD REMOVAL RATE COEFFICIENTS

Month	BOD_5 (Lo) $\frac{mg}{l}$	BOD_5 (Le) $\frac{mg}{l}$	BOD (Lo-Le) $\frac{mg}{l}$	MLSS (Xa) $\frac{mg}{l}$	k 1/mg-hr
October 71(1)	59.8	13.8	46.0	191	.0011
November (1)	65.0	11.1	53.9	140	.0022
December (2)	55.5	20.9	34.6	136	.0013
January 72(2)	52.8	20.2	32.6	117	.0029
February	60.9	10.2	50.7	166	.0012
March	48.7	7.3	41.4	101	.0023
April	42.7	5.1	37.6	80	.0038
May	50.2	7.1	43.1	75	.0034
June	44.6	6.1	38.5	119	.0022
9-Mo Avg	53.3	11.3	42.0	125	.0023
4-Mo avg(3)	46.6	6.4	40.2	94	.0028

(1) k calculated with 15 hour retention time. Low levels in lagoon due to errosion of dykes.

(2) k calculated with 9 hour retention time. Extremely low levels due to repair work in progress on dykes.

(3) March to June, 1972.

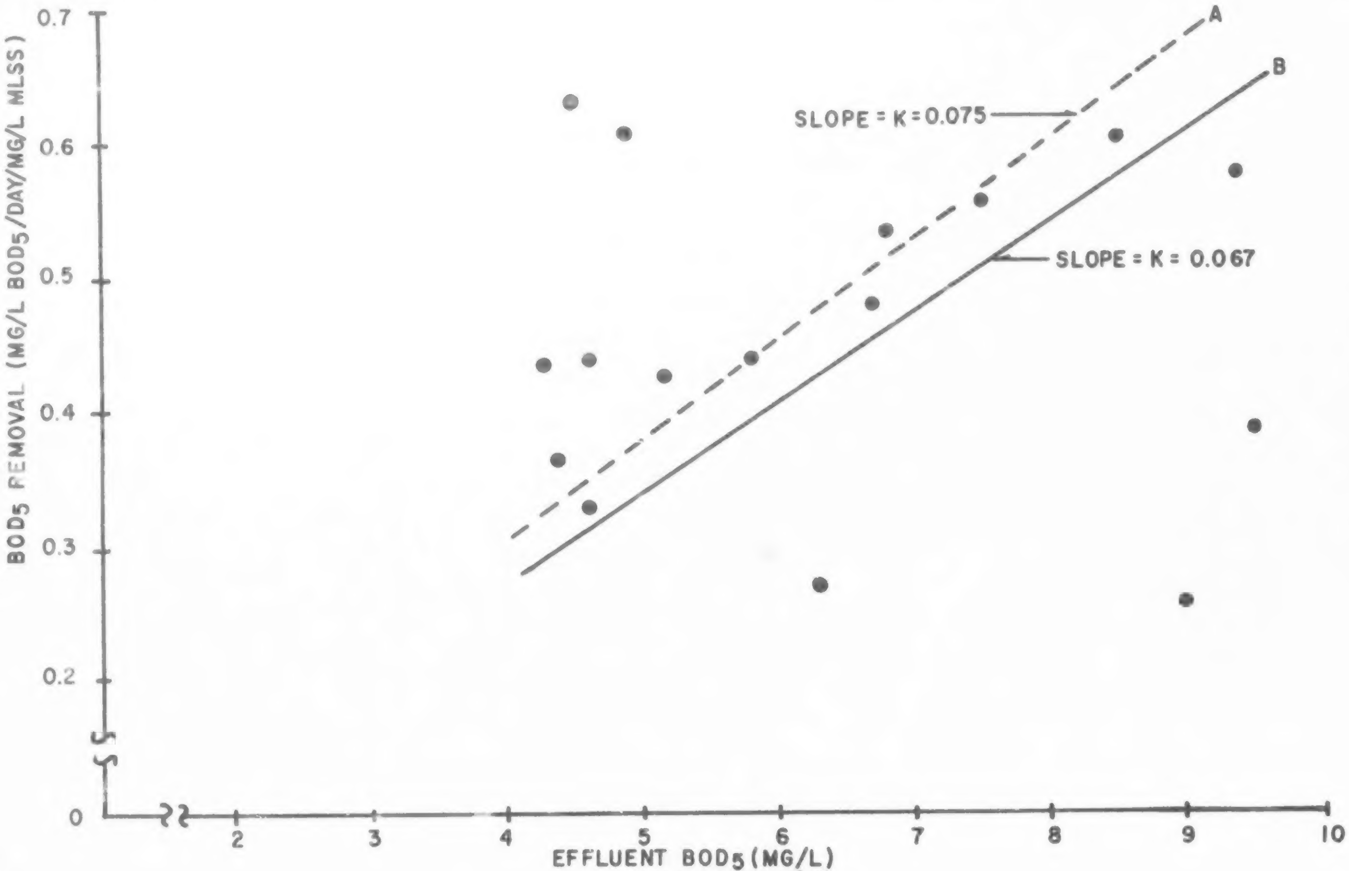

FIGURE 16

BOD_5 REMOVAL VS. EFFLUENT BOD_5-REMOVAL RATE COEFFICIENT FOR AERATED LAGOON
WEEKLY AVERAGES FOR MARCH-JUNE, 1972

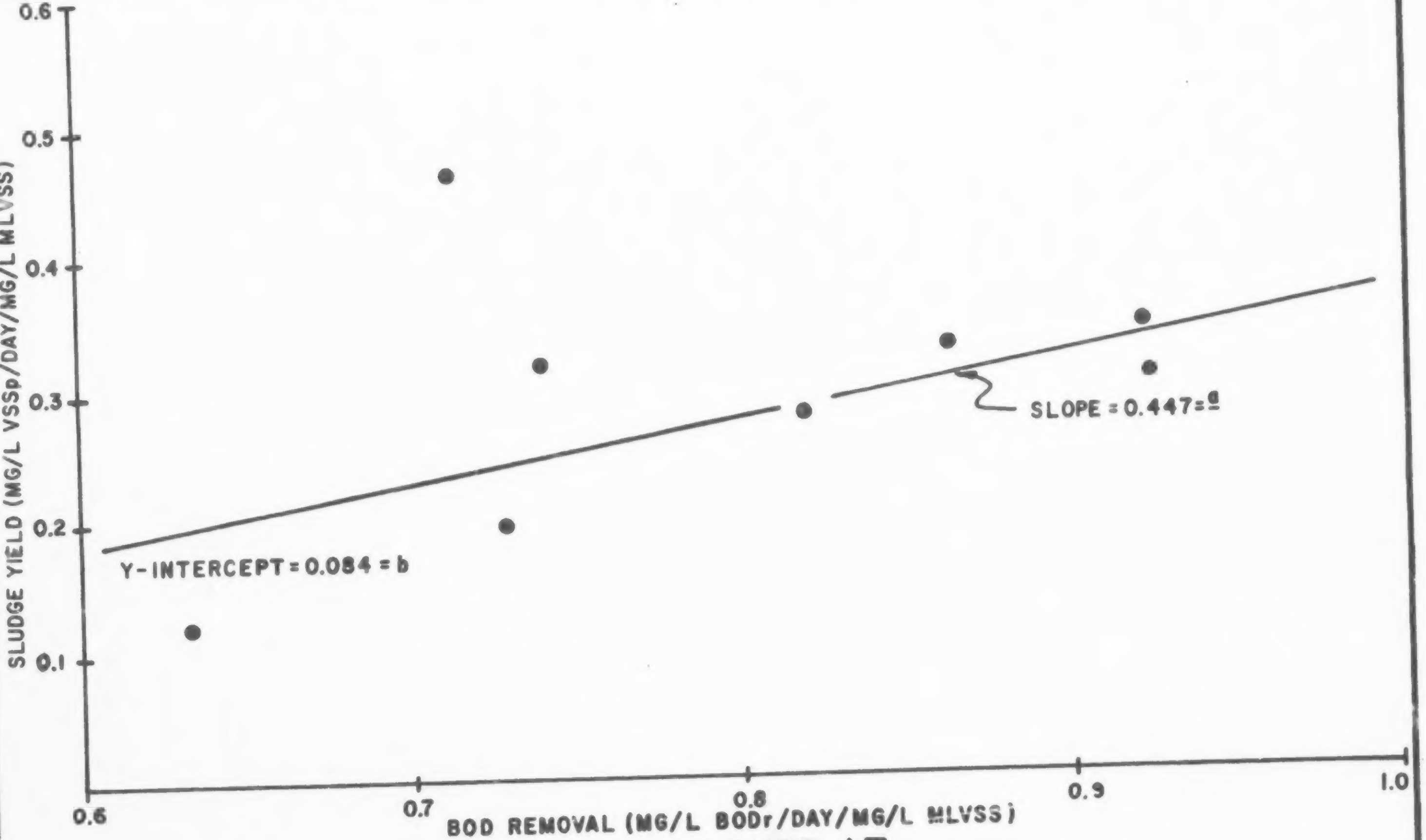

FIGURE 17

SLUDGE YIELD VS. BOD_5 REMOVAL- DETERMINATION OF BIOLOGICAL OXIDATION CONSTANTS "a" AND "b" FOR AERATED LAGOON FOR MARCH-JUNE, 1972

The aerated lagoon's irregular geometry was dictated by the physical location of the large impoundment lagoon and the railroad spur that crosses the southeast corner of the impoundment pond.

Solids, comprised mainly of carbon black and rubber that had previously settled out in the lagoon, were not removed prior to placing the aerated lagoon into operation. The aerated lagoon required sufficient time to reach a solids stabilization period after it was placed in operation.

Initial lagoon MLSS levels tested near 300 mg/l, with MLSS levels around 200 mg/l at the beginning of the demonstration period. MLSS levels during the last four months' operation averaged near 100 mg/l, close to the MLSS levels found during in-plant laboratory bio-oxidation studies.

SYSTEM PERFORMANCE

Table 18 has been constructed to show a comparison between actual system performance and design target performance for several of the more pertinent wastewater parameters.

TABLE 18

SYSTEM PERFORMANCE

Parameter		Final Discharge
Flow (MGD)		3.55
BOD_5	-lbs/day	340
	mg/l	11.5
Dissolved Oxygen	(mg/l)	5.0
Suspended Solids	-lbs/day	857
	mg/l	29
Oil and Grease	-lbs/day	213
	mg/l	7.2
Total Chromium	lb/day	1.4
	mg/l	.049
Phenols	-lbs/day	1.1
	mg/l	.038
Chlorides	-lbs/day	33,741
	mg/l	1,141
Sulfates as SO_4		21,705
	mg/l	734

Clarification - Overall suspended solids removal averaged 85.2 percent during the demonstration period. Final effluent suspended solids averaged 29 mg/l. Average suspended solids reductions of 73.9 percent and 78.7 percent were accomplished around the primary and secondary air flotation units respectively during the nine-month period. Suspended solids removal efficiencies were lower than those accomplished during pilot air flotation studies. Turbulence within the mixing and flocculation equipment hindered floc development and consequent solids removal. Equipment modifications directed at eliminating turbulence should enable the clarification units to reach higher removal levels.

The lower suspended solids removals during May and June, 1972 were the result of worn skimmer seals on the sludge removal rakes. (The rubber skimmer seals were the original ones, having been in service for over a year.) Replacement of the seals has resulted in improved solids removal for both clarifiers. (See Figure 21)

Average oil and grease removals of 82.2 percent were accomplished during the demonstration period, as shown in Table 15. The average oil and grease content of the final effluent was 7.1 mg/l. Improved solids removal during clarification would result in lower oil and grease levels in the final effluent, since the oil exists mainly in the suspended solids, and not as free or floating oil.

Average BOD_5 and COD reductions of 29.1 percent and 63.8 percent, respectively, were accomplished during primary clarification. These were somewhat higher (approximately 10 percent) than those accomplished during the pilot studies. Overall BOD_5 and COD reductions averaged 84.2 percent and 83.7 percent during the demonstration period (See Table 15). Figures 18 and 19 were constructed to show influent and effluent BOD_5 and COD levels during the nine-month period. Effluent results reflect the increase in BOD_5 and COD levels during the December 15, 1971 and January 15, 1972 period when maintenance work was being performed on the aerated lagoon dykes. The BOD_5 and COD influent curves show a downward trend over the nine-month period as the result of better in-plant housekeeping.

An effluent BOD_5 level of 7 mg/l or less was met during the last four months of the demonstration period. Lagoon performance has been very satisfactory following the maintenance period. Figure 20 shows the influent-effluent TOC levels during the demonstration period. The total organic carbon instrument was placed in operation during the second

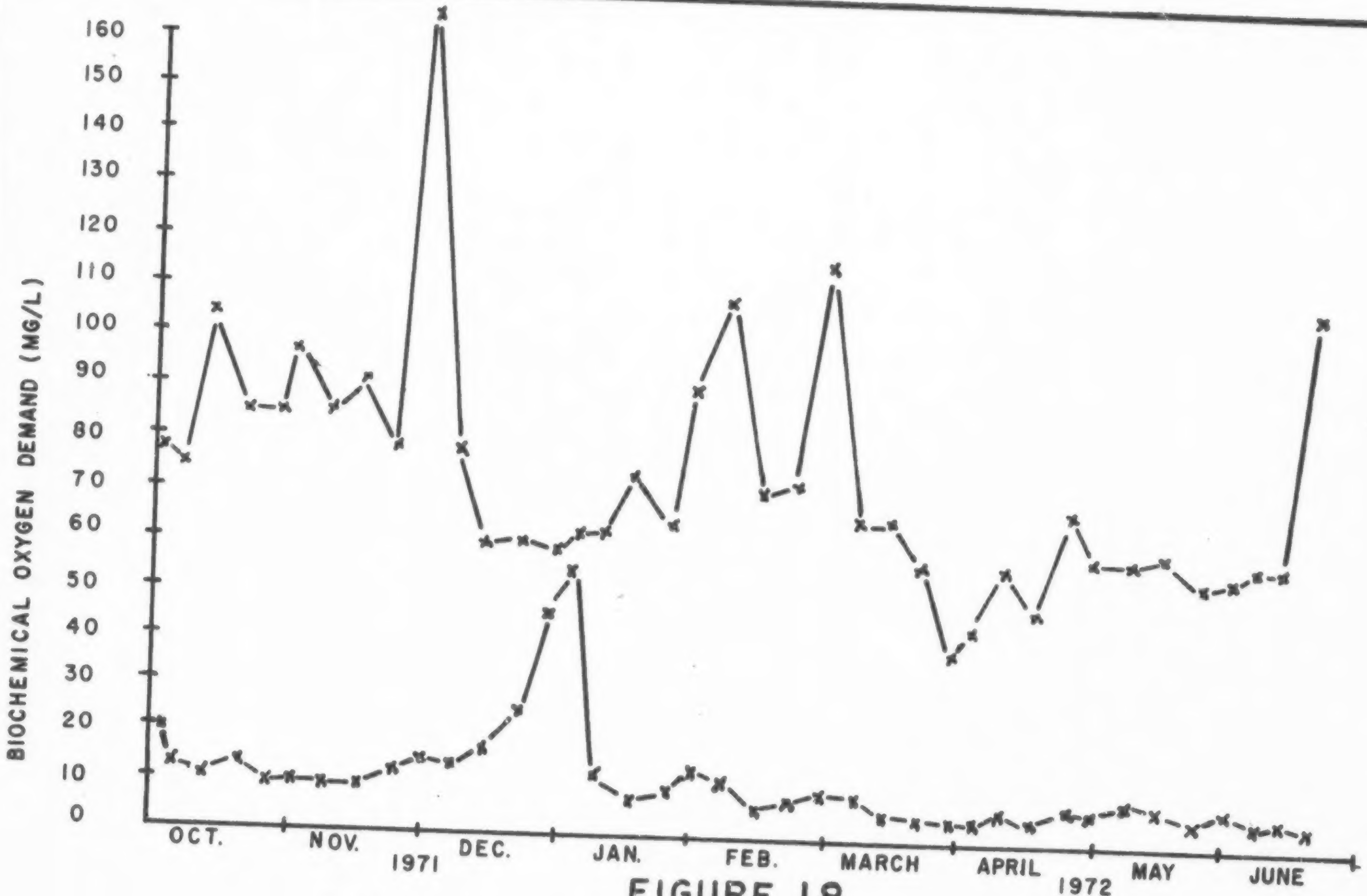

FIGURE 18

BIOCHEMICAL OXYGEN DEMAND INFLUENT AND EFFLUENT
WEEKLY AVERAGES OCT.,1971-JUNE,1972

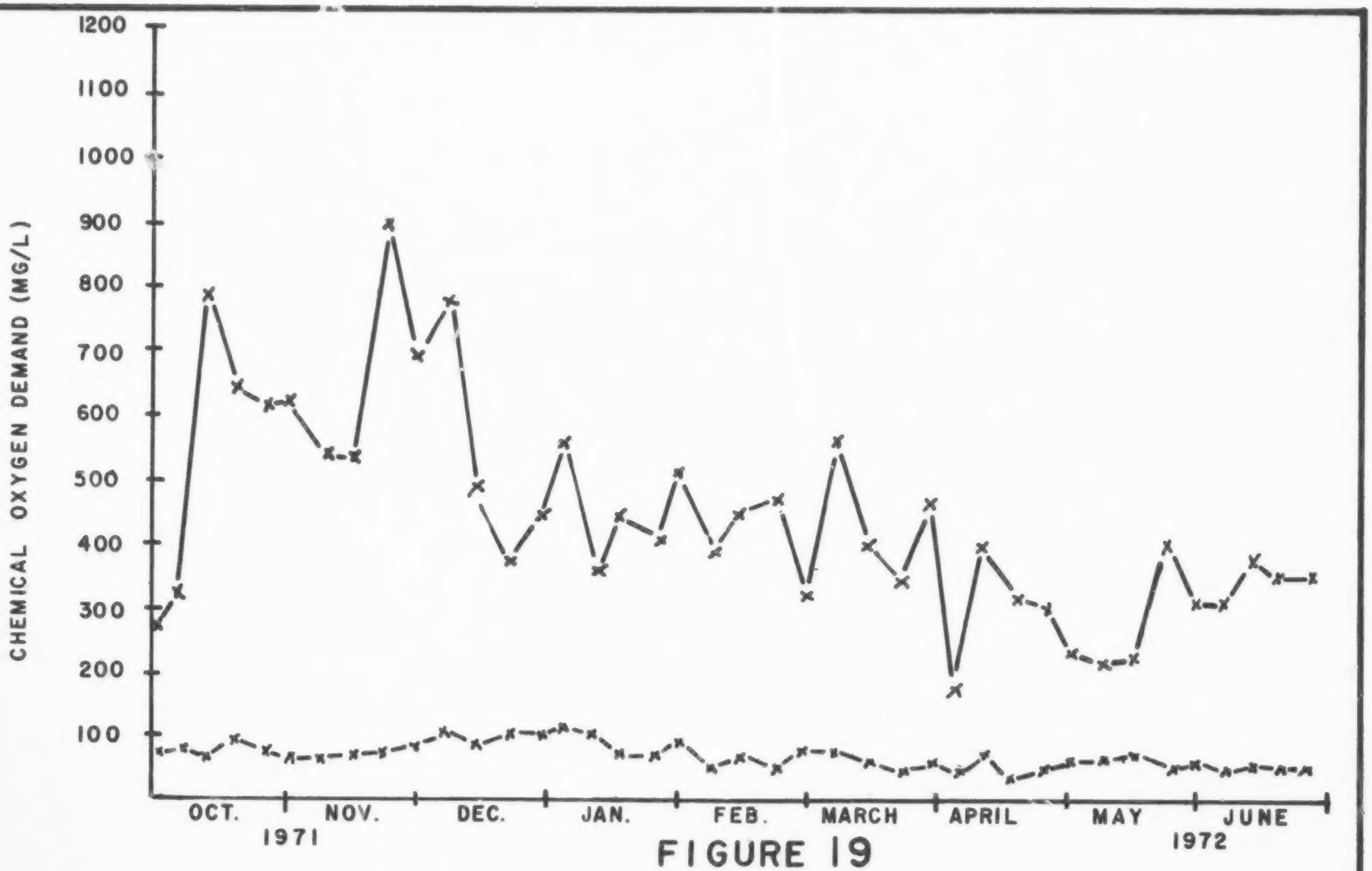

FIGURE 19

CHEMICAL OXYGEN DEMAND INFLUENT AND EFFLUENT

WEEKLY AVERAGES OCT., 1971–JUNE, 1972

week in November, 1971, following a delay in receiving the instrument. An average TOC reduction of 61.5 percent was observed with an effluent TOC average of 24 mg/l during the demonstration period.

Average Phenol and Chromium reductions of 74.5 percent and 75.8 (Table 15) were accomplished during the demonstration period. Complete removal of these chemicals is not expected with the existing wastewater treatment system.

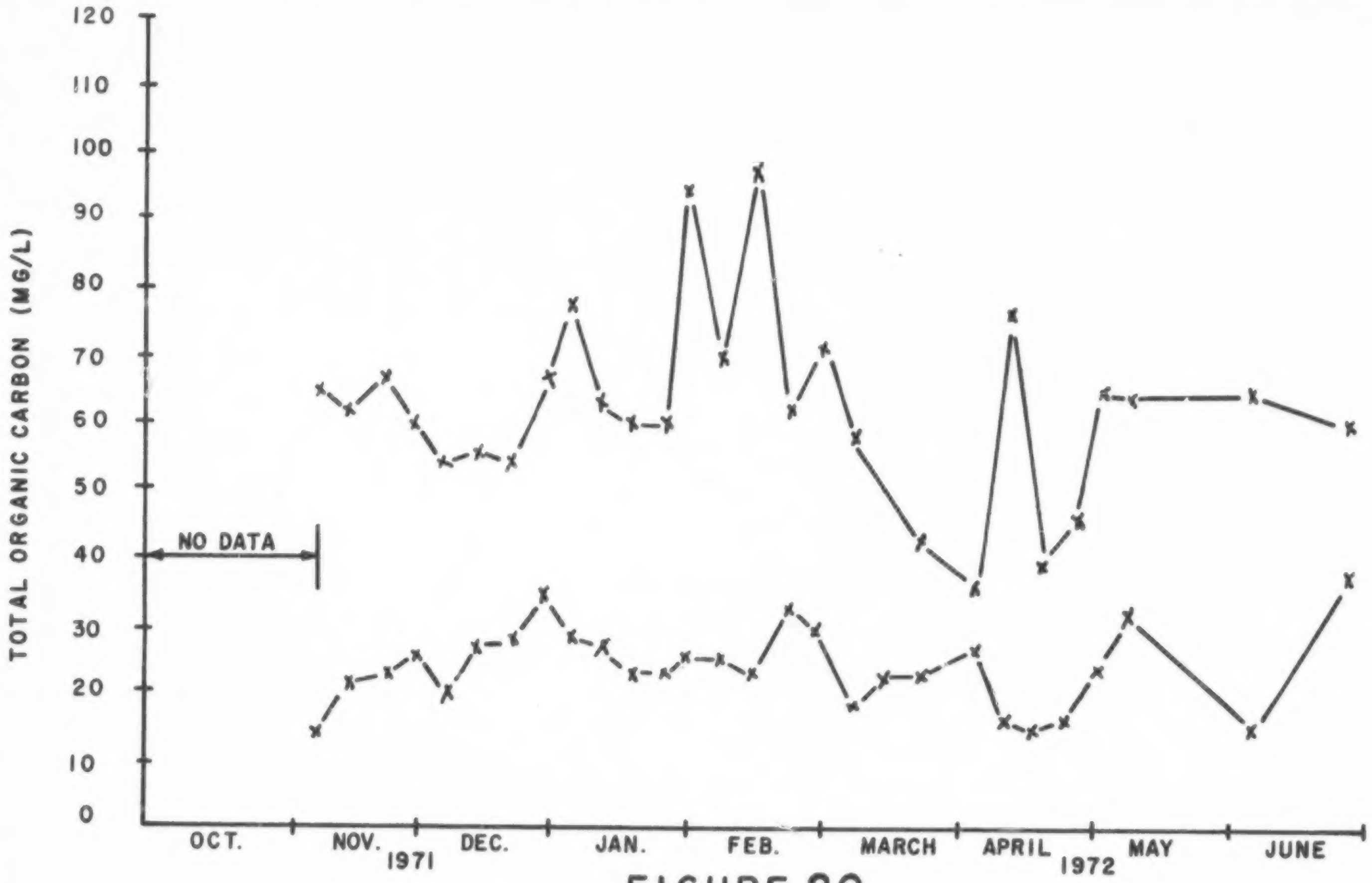

FIGURE 20

INFLUENT AND EFFLUENT TOTAL ORGANIC CARBON
WEEKLY AVERAGES OCT., 1971–JUNE, 1972

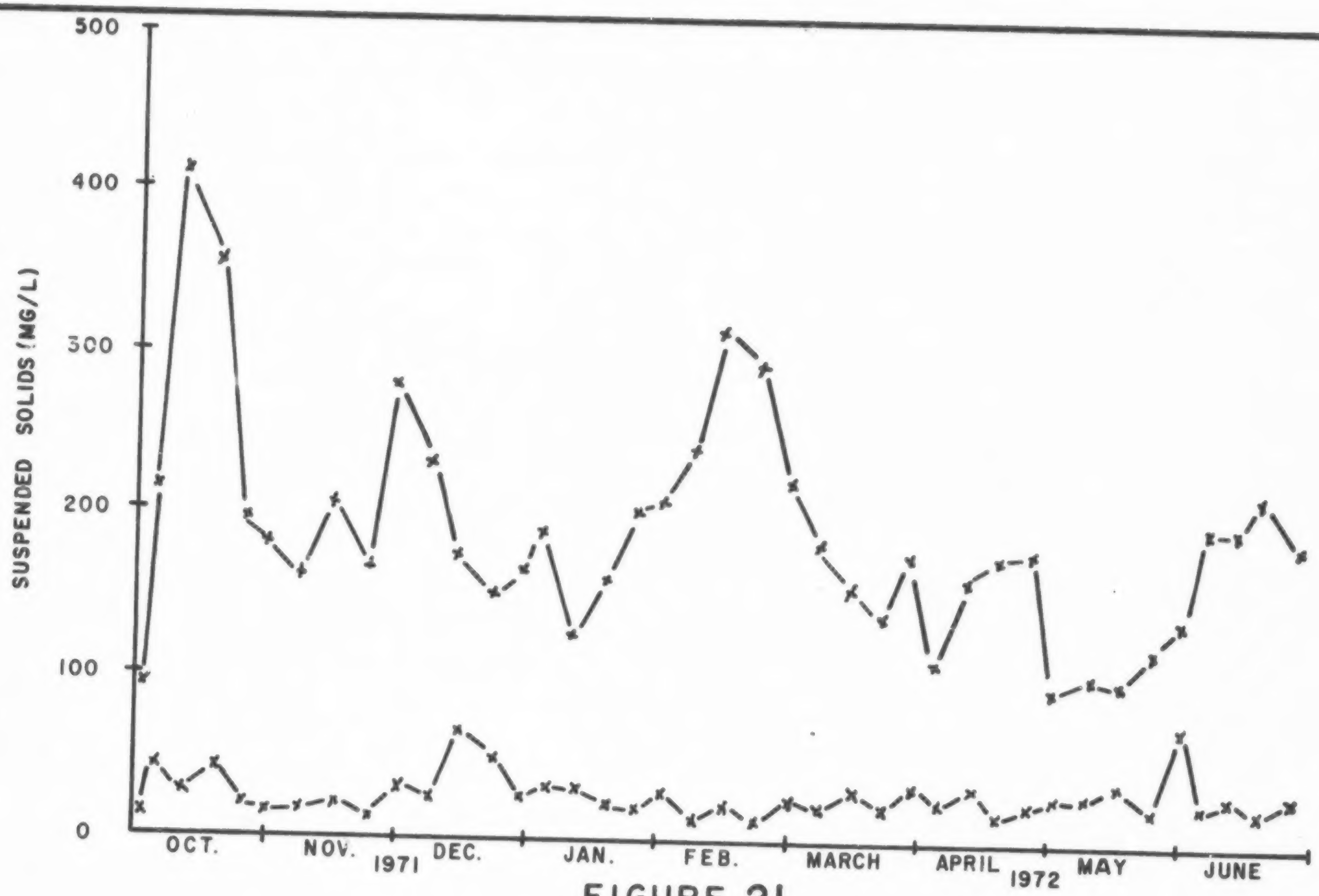

FIGURE 21
INFLUENT AND EFFLUENT SUSPENDED SOLIDS
WEEKLY AVERAGES OCT., 1971 - JUNE, 1972

SECTION IX

FINANCIAL CONSIDERATIONS

CONSTRUCTION COSTS

The total cost of the wastewater treatment facilities was $1,472,528, including engineering costs. A detailed equipment cost breakdown is included in Appendix D.

Included in the engineering costs are survey work, water testing, pilot plant testing, producing plans and specifications, obtaining quotations and bids, and supervision and inspection of construction.

Some factors that increased the total cost for this particular case that would not necessarily contribute to the cost of similar facilities are listed below.

1. The remote location of the aerated lagoon required pumping of the wastewater over great distances between the clarifiers and the lagoon.
2. Due to anticipated high chemical costs, more instrumentation was provided than would be required for most similar treatment facilities.
3. Two electrical substations were required due to the distance between the aerated lagoon and the remainder of the treatment facilities.

OPERATING AND MAINTENANCE COSTS

The total operating and maintenance cost for the nine-month demonstration period was $367,274, which includes $57,404 spent for sludge disposal by contract, but excludes all costs attributable to the demonstration studies.

The annual operating and maintenance cost, excluding sludge disposal costs, would normally be $409,751, or $0.336 per 1,000 gallons of raw wastewater treated.

Sludge was disposed of by a contractor for five and one-half months during the demonstration period at a cost of $0.015 per gallon, or $57,404 for the total volume handled. At this rate, the annual cost of sludge disposal would have been $125,245, or $0.103 per 1,000 gallons of raw wastewater treated.

Present impounding of the sludge has delayed the cost of disposal while a more desirable means of disposal is sought.

A breakdown of operating and maintenance costs is included in the following table.

TABLE 19

OPERATING MAINTENANCE AND DEMONSTRATION COST

ITEM	Nine-month Demonstration Period Operating & Maintenance Costs	 Demonstration Costs	Projected Annual Operating and Maintenance Costs
DEMONSTRATION COSTS			
Salaries and Wages		$ 104,423	
Fringe Benefits		26,106	
Equipment		80,665	
Supplies		1,722	
Travel		1,331	
Indirect Costs		14,538	
Total		$ 228,785	
OPERATING & MAINTENANCE COSTS			
Salaries and Wages	$ 52,071		$ 69,426
Fringe Benefits	15,527		20,702
Supplies	140,068		186,753
Utilities	25,216		33,620
Repairs	76,988		99,250
Sub Total	309,870		409,751
Sludge Disposal	57,404		125,245
TOTALS	$ 367,274	$ 228,785	$ 534,996

TOTAL ANNUAL COSTS

Refer to Table 20 for a tabulation of the annual costs. The interest listed is the approximate average annual interest on the unpaid balance for a loan in the amount of the capital cost of the facilities, at an interest rate of 7 percent per annum. The equipment replacement cost and depreciation is estimated to be 10 percent of the capital cost.

With a total annual cost of $608,542, which excludes sludge disposal costs, the cost of treatment was $0.499 per 1,000 gallons of raw wastewater treated. If sludge disposal costs of $0.015 per gallon were included in the operating costs, the total annual cost would be $733,787, or $0.602 per 1,000 gallons of raw wastewater treated.

TABLE 20

TOTAL ANNUAL COSTS

Item	Annual Cost
Interest on Capital Cost of $1,472,528	$ 51,538
Annual Operating and Maintenance Cost	409,751
Estimated Equipment Replacement and Depreciation	147,253
Total Annual Cost (Excluding Sludge Disposal Costs)	$ 608,542
Sludge Disposal Costs	$ 125,245
Total Annual Cost (Including Sludge Disposal Costs)	$ 733,787

Costs are presented both with and without sludge disposal due to the extremely high cost of the method of disposal utilized. It is felt that a more economical means of disposing of this particular sludge can be found. It is also felt that wastewater from another synthetic rubber plant utilizing identical processes will produce a sludge of an entirely different nature due to slight variations in process equipment and operating procedures. Even a slight variation in the nature of the sludge could make it more amenable to conventional methods of dewatering.

SECTION X

ACKNOWLEDGEMENTS

This project was supported in part by Environmental Protection Agency Demonstration Grant No. 12110 GLP. Appreciation is expressed to Mr.William J. Lacy, Chief of Industrial Pollution Control, ORD; Mr. Charles R. Ris, Project Manager; and Mr. George Putnicki and Mr. Joseph W. Field, Project Officers, for their help during the course of the project.

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SECTION XI

REFERENCES

1. Busch, A. W., "Biochemical Oxidation of Process Waste Water," Chemical Engineering, Vol. 72, No. 5, pp 71-76 (March 1, 1965)

2. Busch, A. W., "Liquid Waste Disposal System Design," Chemical Engineering, Vol. 72, No. 7, pp 83-86 (March 29, 1965)

3. Busch, A. W., "Treatability Versus Oxidizability of Industrial Wastes and the Formulation of Process Design Criteria," Proc. 16th Industrial Waste Conference, Purdue University (1961)

4. Characklis, W. G., and Busch, A. W., "Industrial Wastewater Treatment," Chemical Engineering Deskbook, Vol. 79, No. 10, McGraw-Hill, Inc. (May 8, 1972)

5. Eckenfelder, W. W., "Design Procedures for Wastewater Treatment Processes," Center for Research in Water Resources, University of Texas (October, 1968)

6. Eckenfelder, W. W., Industrial Water Pollution Control, McGraw-Hill Book Co., New York (1966)

7. Eckenfelder, W. W., "Principles and Practice of Industrial Water Treatment," Seminar on Water Pollution Control in the Chemical Industry, University of Texas (1969)

8. Ford, Davis L., "Laboratory Methology for Developing Biological Treatment Information," (Date of publication unknown.)

9. Geinopolos, Anthony, and Katz, W. J., "Primary Treatment," Chemical Engineering Deskbook, Vol. 70, No. 22, McGraw-Hill, Inc. (October 4, 1968)

10. Gloyna, E. F., and Aquirre, I. J., "Designs for Waste Stabilization Ponds and Aerated Lagoons," XI AIDIS Congress, Quito, Ecuador, S.A. (July 21-29, 1968)

11. Gloyna, E. F.; Brady, S. O.; and Lyles, H.; "Use of Aerated Lagoons and Ponds in Refinery and Chemical Waste Treatment," Journal Water Pollution Control Federation, Vol. 41, No. 3, Part 1, pp 429-439 (March 19, 1969)

12. Lungren, Hans, "Air Flotation Purifies Wastewater from Latex Polymer Manufacture," *A.I.Ch.E. 65th Annual Meeting*, Cleveland, Ohio (May 4-7, 1969)

13. Lundgren, Hans, "Recent Advances in Air Flotation Technology," *TAPPI Sixth Annual Water and Air Conference*, Jacksonville, Fla. (April 28-30, 1969)

14. Ross, R. D., and others, *Industrial Waste Disposal*, Reinhold Book Corp., New York (1968)

SECTION XII

APPENDIXES

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APPENDIX A

PHOTOGRAPHS

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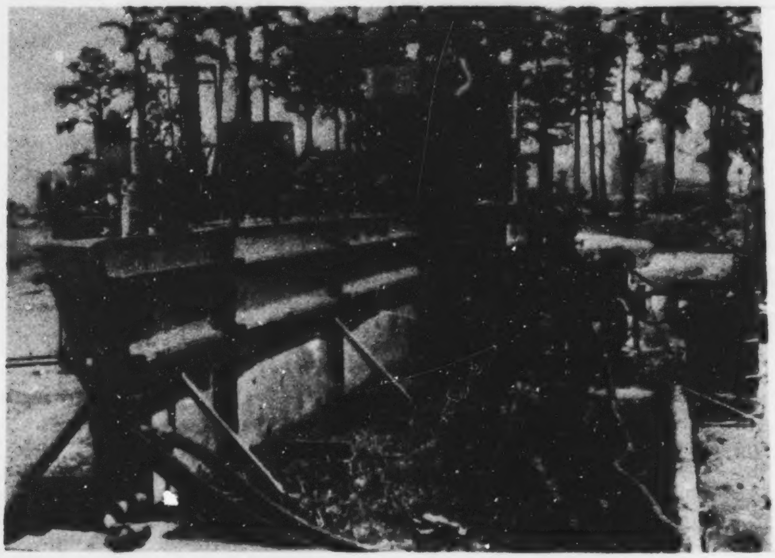

FIGURE A-1

PILOT AIR FLOTATION UNIT

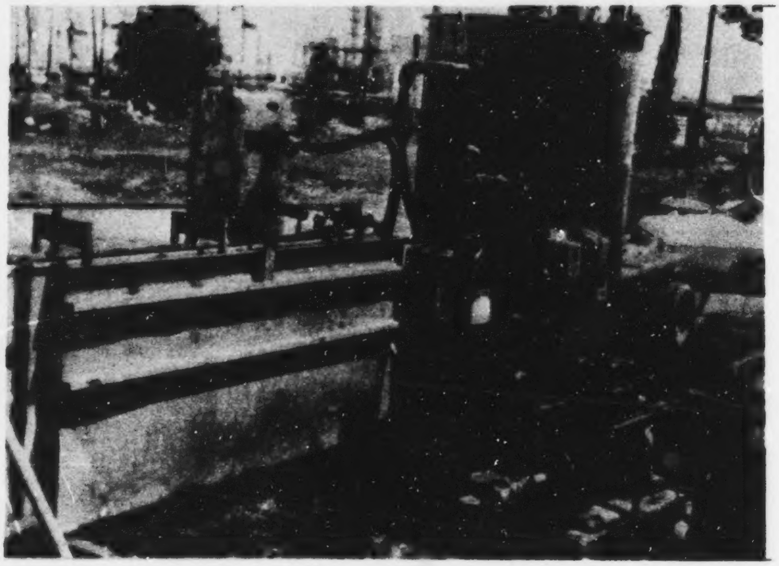

FIGURE A-2

PILOT AIR FLOTATION UNIT RECYCLE PRESSURIZATION
AND CHEMICAL FEEDING EQUIPMENT

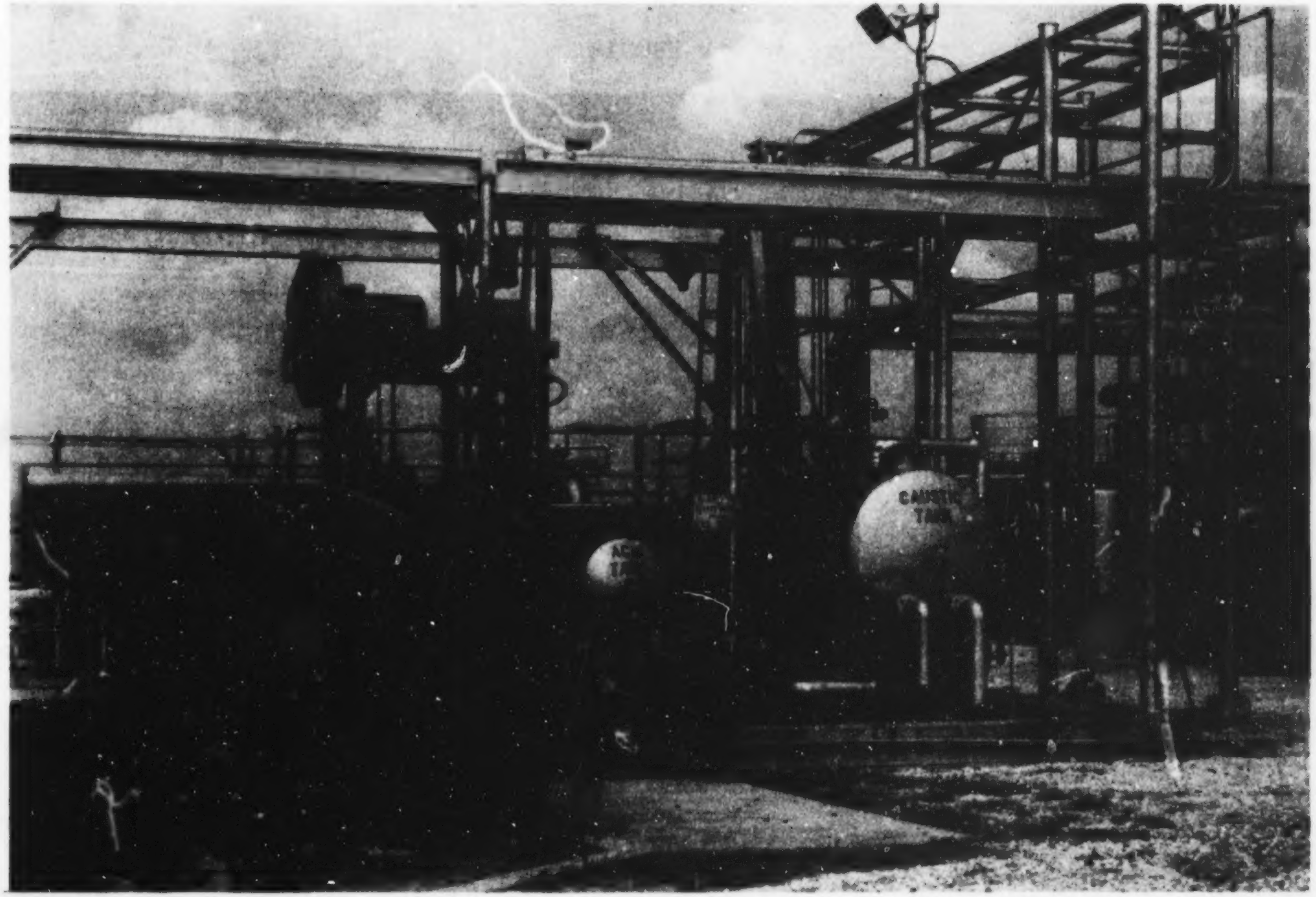
CAUSTIC TANK

FIGURE A-3

MECHANICAL BAR SCREEN AND WET WELL NEUTRALIZATION FACILITIES

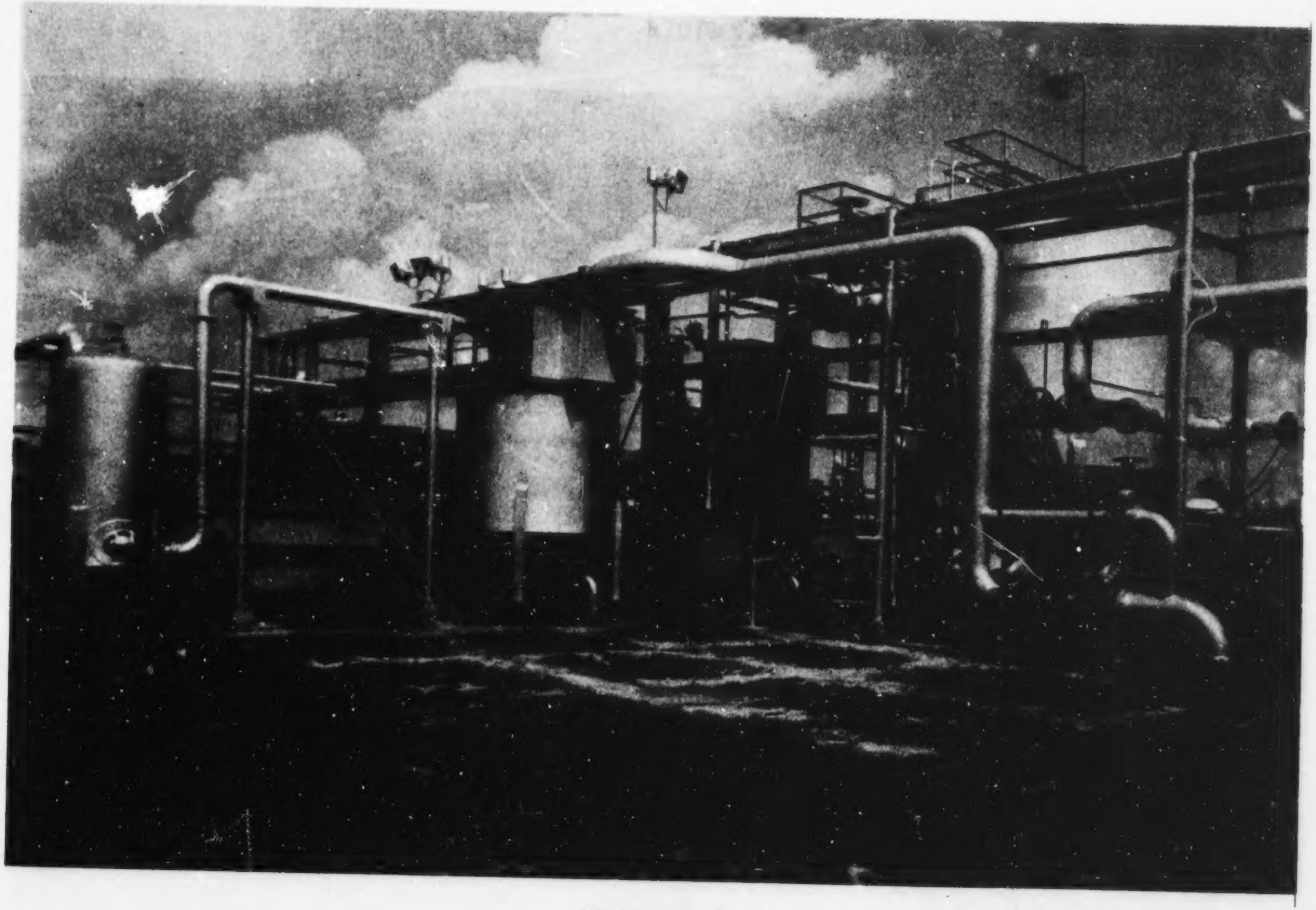

FIGURE A-4

SOUTH SIDE OF AIR FLOTATION CLARIFIERS
ALUM MIX TANK, FLASH MIXING TANKS, FLOW MEASURING BOXES, AND PRESSURE RETENTION TANK

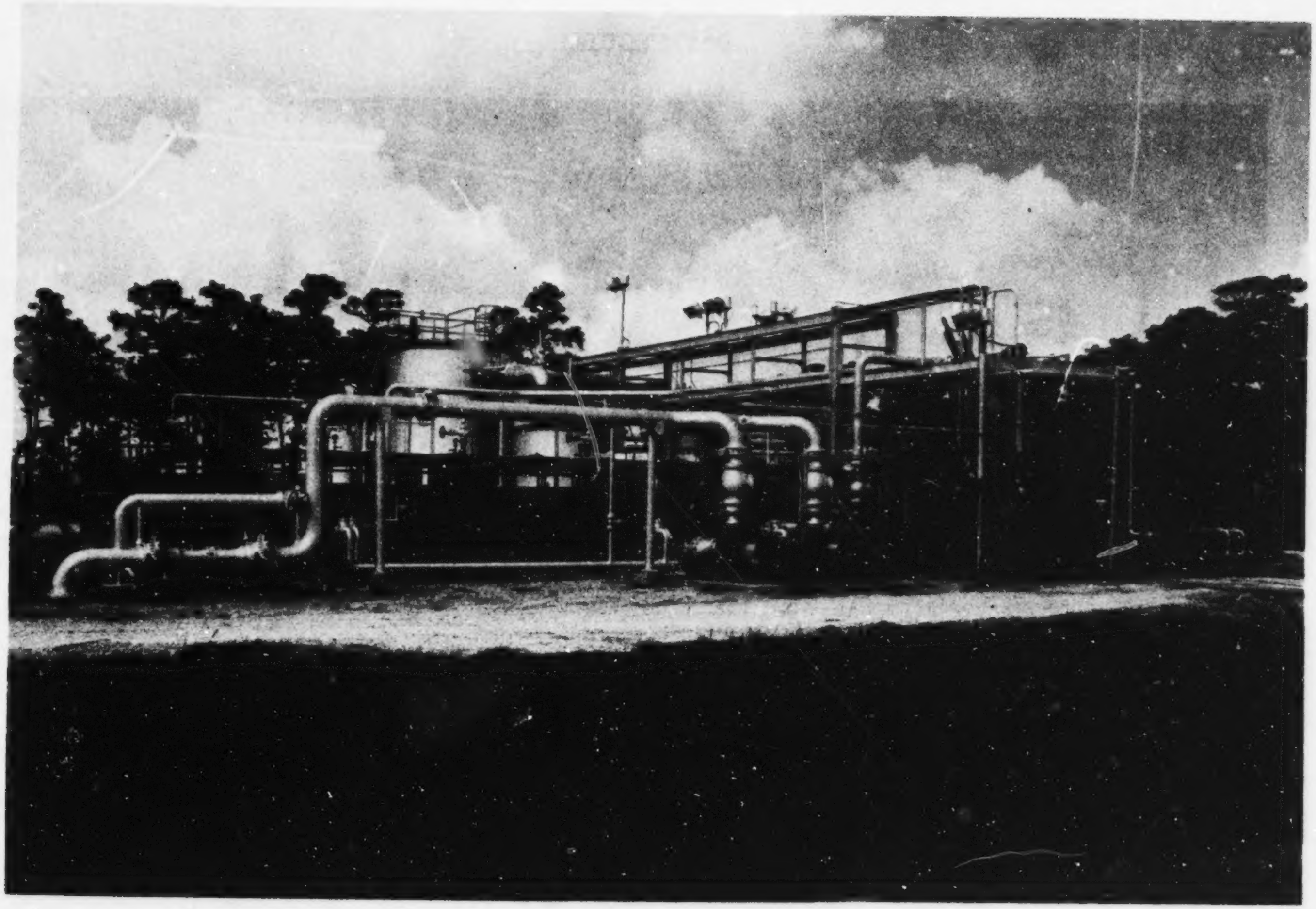

FIGURE A-5

NORTH SIDE OF AIR FLOTATION CLARIFIERS - SLUDGE, RECYCLE, AND CLARIFIED EFFLUENT PUMPS

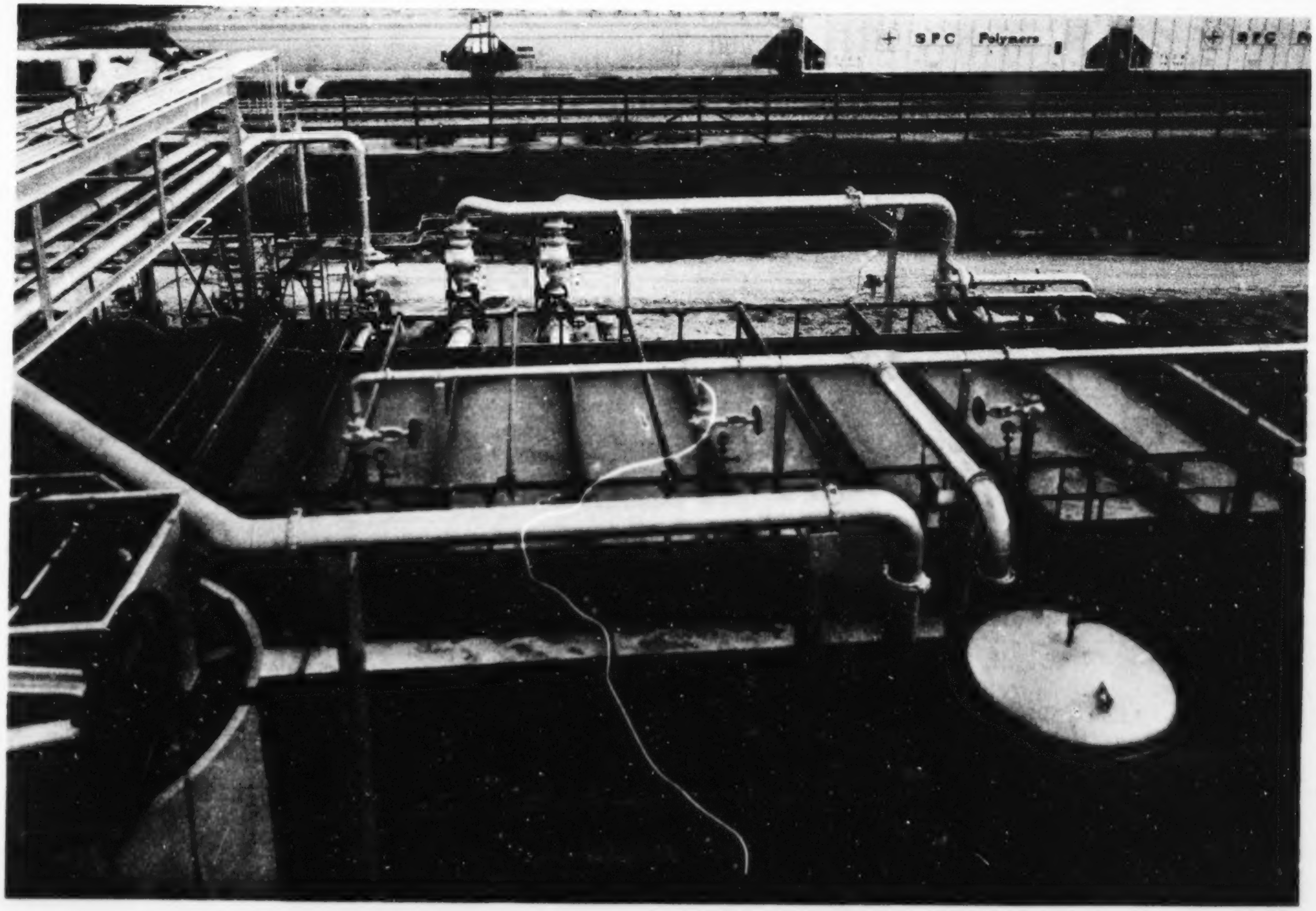
SPC Polymers
SPC

FIGURE A-6

PRIMARY AIR FLOTATION CLARIFIER FROM TOP OF ALUM MIX TANK

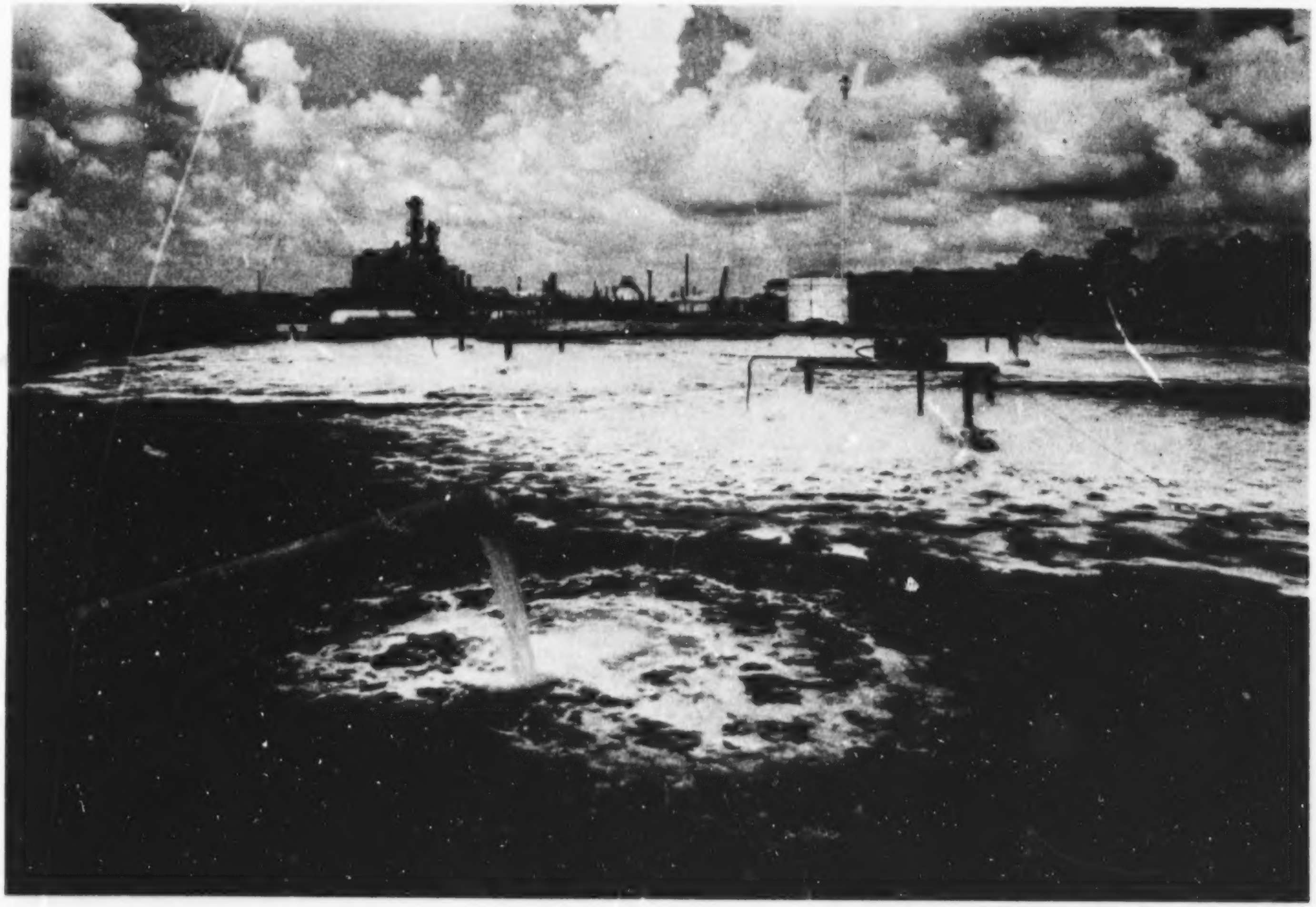

FIGURE A-7

AERATED LAGOON

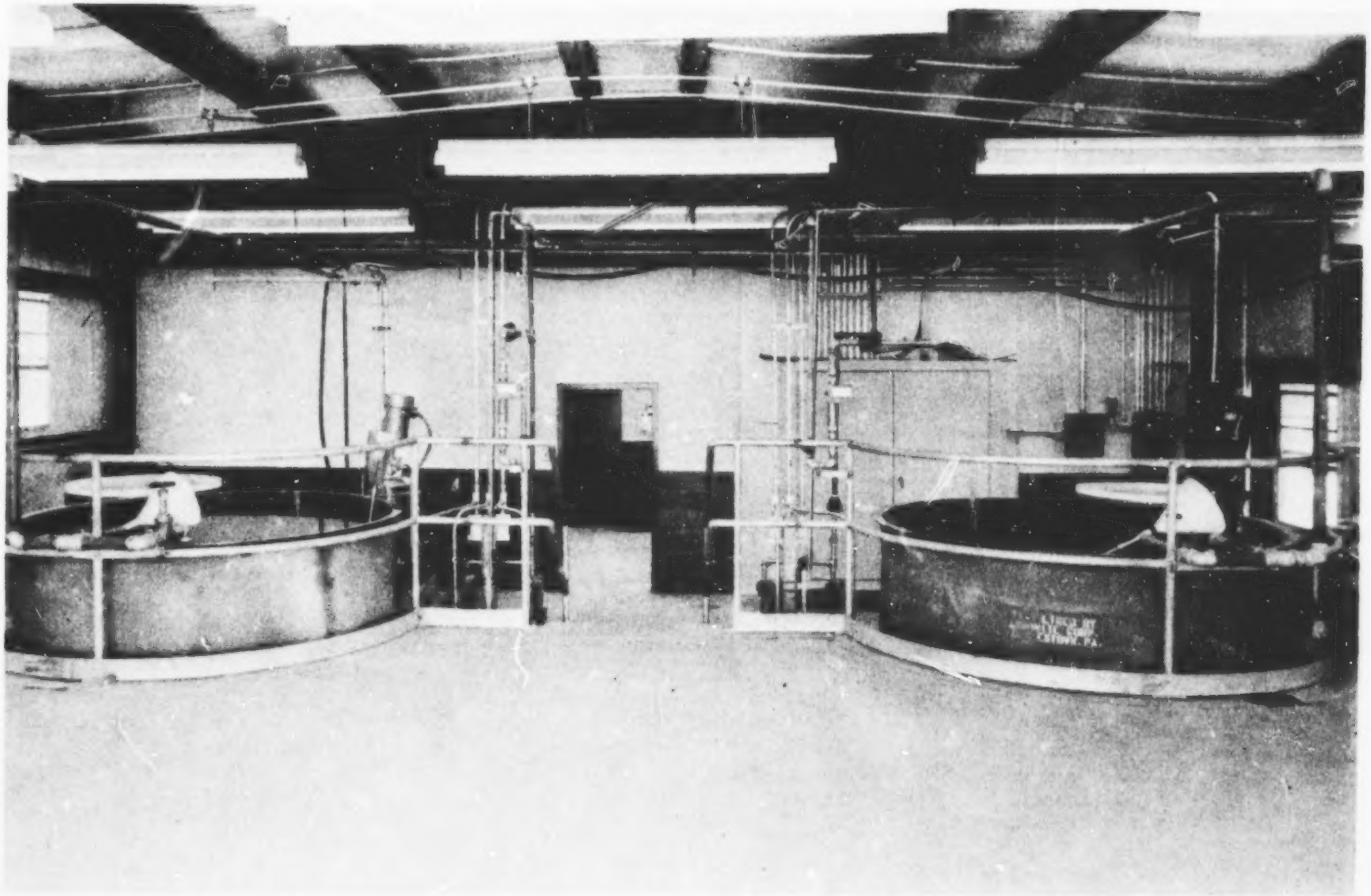

FIGURE A-8

FLOCCULENT AID MAKEUP TANKS

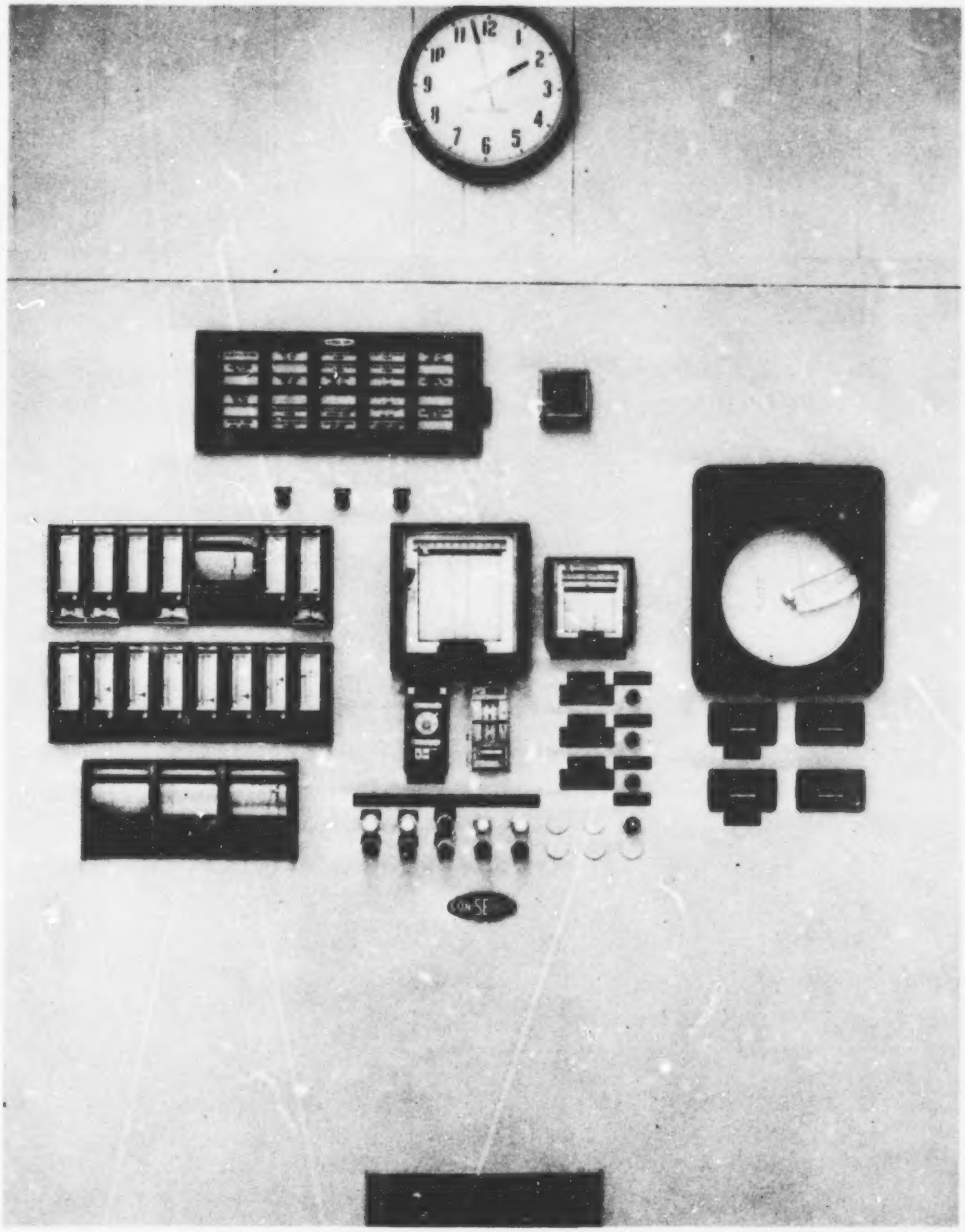

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FIGURE A-9

CONTROL PANEL
WASTEWATER TREATMENT SYSTEM

APPENDIX B

DEVELOPMENT AND CONSTRUCTION TIMETABLE

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TABLE B-1

DEVELOPMENT AND CONSTRUCTION TIMETABLE

The following is a schedule of the major steps in the development and construction of the wastewater treatment facilities.

Date		Phase of the Project
From	To	
July 1, 1969	Aug. 25, 1969	Obtained proposals outlining scope of work and estimated cost of plant survey from prospective consultants.
Aug. 25, 1969	Aug. 27, 1969	Selection of consultant for plant survey.
Sept. 30, 1969	Nov. 24, 1969	Performance of plant survey and treatment studies by the consultant.
Nov. 25, 1969	Apr. 2, 1969	Performance of laboratory testing and development of a plan of action by plant personnel.
Dec. 1, 1969	Apr. 2, 1970	Development of preliminary specifications for the treatment facilities by plant personnel.
Jan. 22, 1970	Dec. 31, 1970	Retention of an engineering firm to develop flow diagrams, finalize specifications, and obtain competitive quotations.
March 10, 1970	Aug. 7, 1970	Pilot testing by plant personnel.
July 27, 1970	Aug. 4, 1970	Evaluation of bids for air flotation units and mechanical aeration equipment.

Date		
From	To	Phase of the Project
Aug. 4, 1970	Dec. 14, 1970	Issuance of purchase orders for the required equipment.
Sept. 1, 1970	Dec. 1, 1970	Performance of engineering and drafting for construction.
Oct. 1, 1970	Jan. 20, 1971	Obtained bids for major portions of work required.
Nov. 15, 1970	Feb. 25, 1971	Issuance of contracts for construction and equipment erection.
Nov. 20, 1970	May 26, 1971	Construction and erection of equipment.
May 27, 1971	Oct. 1, 1971	Start-up of equipment and correction of defects.
Oct. 1, 1971	July 1, 1972	Demonstration period.

APPENDIX C

DESIGN DATA

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TABLE C-1

WASTEWATER HANDLING AND TREATING EQUIPMENT

Mechanically Cleaned Bar Screen

No.	1
Bar Spacing	1 Inch
Channel Width	3' 0"
Channel Depth	6' 4"
Flow Depth	3' 0"
Modes of Operation	
1. Automatic	Timed on and off
2. Hand	Pushbutton Start and Stop

Wet Well Pumps

No.	3
Type	Centrifugal
Capacity	2100 gpm
Total Head	52 Feet

Alum Coagulation Vessel

Diameter	15' 0"
Height (Straight Sides)	12' 6"
Capacity	17,000 Gallons
Top	Open
Bottom	Cone

Alum Coagulation Vessel Agitator

Size	5 HP
Speed	188 rpm
No. of Impellers	2
Diameter of Impellers	24 Inches

Primary Flow Measuring Box

No.	1
Width	4' 0"
Length	7' 0"
Depth	4' 0"
Primary Flow Measuring Element	Orifices with free discharge
No. of Orifices	8
Diameter of Orifices	5.625 Inches

Primary Flash Mixing Tank

Diameter	9' 0"
Height (Straight Side)	7' 6"
Top	Open
Bottom	Dished head
Volume	3,375 Gallons

Primary Clarifier Floc Former Compartment

Width	48' 8"
Length	6' 0"
Depth (Working)	4' 2"

Primary Clarifier Floc Former Agitator

Horsepower	1 HP
Speed	13.25, 9.92, 6.63, & 3.30 rpm
Diameter of Paddle Reels	3' 0"

Primary Clarifier Inlet Compartment

Width	48' 8"
Length	3' 0"
Depth (Working)	3' 10"

Primary Clarifier Air Flotation Compartment

Width	48' 8"
Length	15' 0"
Depth (Average Working)	4' 0"

Primary Clarifier Treated Liquid Compartment

Width	3' 0"
Length	48' 8"
Depth (Working)	4' 2"

Primary Clarifier Effluent Compartment

Width	3' 6"
Length	21' 0"
Depth	2' 10"

Primary Clarifier Recycle Pump

No.	1
Type	Centrifugal
Capacity	1,000 gpm
Total Head	150 Feet

Primary Clarifier Pressure Retention Tank

No.	1
Diameter	4' 6"
Height (Straight Shell)	8' 6"
Capacity	1,050 Gallons
Design Pressure	75 psi

Primary Clarifier Air Flow Meter

No.	1
Type	Variable area
Flow Range	0-10 SCFM
Inlet Pressure	50 psi
Inlet Temperature	70°F

Clarified Effluent Pumps

No.	2
Type	Centrifugal
Capacity	3,500 gpm
Total Head	69 Feet

Primary Flotation Compartment Skimmers

No. of Flights	18
Skimmer Speed (Ft per min)	0 to 15
Driver Horsepower	1

Primary Sludge Transfer Pump

No.	1
Type	Centrifugal
Capacity	80 gpm
Total Head	45 Feet

Lagoon Effluent Transfer Pumps

No.	2
Type	Centrifugal
Capacity	3,500 gpm
Total Head	69 Feet

Mechanical Aerators

No.	6
Size	25 HP
Type	Low speed floating
Speed	56 rpm

Final Clarifier Flow Measuring Box

No.	1
Width	4' 0"
Length	7' 0"
Depth	4' 0"
Primary Flow Measuring Element	Orifices with free discharge
No. of Orifices	8
Diameter of Orifices	5.625 Inches

Final Clarifier Flash Mixing Tank

Diameter	9' 0"
Height (Straight Side)	7' 6"
Top	Open
Bottom	Dished head
Volume (Working)	3,375 Gallons

Final Clarifier Floc Former Compartment

Width	48' 8"
Length	6' 0"
Depth (Working)	4' 2"

Final Clarifier Floc Former Agitator

Horsepower	1 HP
Speed	13.25, 9.92, 6.63, & 3.30 rpm
Diameter of Paddle Reels	3' 0"

Final Clarifier Air Flotation Compartment

Width	48' 8"
Length	15' 0"
Depth (Average Working)	4' 0"

Final Clarifier Inlet Compartment

Width	48' 8"
Length	3' 0"
Depth (Working)	3' 10"

Final Clarifier Treated Liquid Compartment

Width	3' 0"
Length	48' 8"
Depth (Working)	4' 2"

Final Clarifier Effluent Compartment

Width	3' 6"
Length	21' 0"
Depth	2' 10"

Final Clarifier Recycle Pump

No.	1
Type	Centrifugal
Capacity	1,000 gpm
Total Head	150 Feet

Final Clarifier Pressure Retention Tank

No.	1
Diameter	4' 6"
Height (Straight Shell)	8' 6"
Capacity	1,050 Gallons
Design Pressure	75 psi

Final Clarifier Air Flow Meter

No.	1
Type	Variable area
Flow Range	0-10 SCFM
Inlet Pressure	50 psi
Inlet Temperature	70°F

Final Clarifier Flotation Compartment Skimmers

No. of Flights	18
Skimmer Speed (Ft per min)	0-15
Driver Horsepower	1

Final Clarifier Sludge Transfer Pump

No.	1
Type	Centrifugal
Capacity	80 gpm
Head	45 Feet

Acid Serving Tank

No.	1
Diameter	2' 6"
Length (Straight Shell)	5' 4"
Capacity	200 Gallons
Material of Construction	Steel

Caustic Serving Tank

No.	1
Diameter	4' 0"
Length (Straight Shell)	10' 0"
Capacity	975 Gallons
Material of Construction	Steel

Alum Serving Tank

No.	1
Diameter	5' 0"
Height	6' 0"
Capacity	820 Gallons
Material of Construction	Fiberglass reinforced polyester

Cationic Polyelectrolyte Tank

No.	1
Diameter	8' 0"
Height of Shell	11' 0"
Capacity	4,136 Gallons
Material of Construction	Fiberglass reinforced polyester

Primary Clarifier Coagulant Aid Makeup Tank

No.	1
Diameter	7' 0"
Height	4' 0"
Capacity	1,150 Gallons
Material of Construction	Steel
Liner	Plastisol

Primary Clarifier Coaguland Aid Feed Tank

No.	1
Diameter	3' 6"
Height	4' 0"
Capacity	288 Gallons
Material of Construction	Polyethylene
Material of Construction - Supporting Shell	Fiberglass reinforced polyester

Final Clarifier Coagulant Aid Makeup Tank

No.	1
Diameter	7' 0"
Height	4' 0"
Capacity	1,150 Gallons
Material of Construction	Steel
Liner	Plastisol

Final Clarifier Coagulant Aid Feed Tank

No	1
Diameter	3' 6"
Height	4' 0"
Capacity	288 Gallons
Material of Construction - Inner Tank	Polyethylene
Material of Construction - Supporting Shell	Fiberglass reinforced polyester

Alum Metering Pumps

No	2
Type	Plunger, single, simplex
Capacity	0-50 gpm
Maximum Discharge Pressure	100 psi

Cationic Polyelectrolyte Metering Pumps

No	3
Type	Plunger, single, simplex
Capacity	1.25 gph
Maximum Discharge Pressure	1,000 psi

Coagulant Aid Metering Pumps

No	4
Type	Plunger, single, simplex
Capacity	50 gph
Maximum Discharge Pressure	100 psi

TABLE C-2

CONTROL INSTRUMENTATION

Wet Well pH Indicator -Recording Controller

Range	5-9 pH
Local Monitor	Yes
Recording at Control Panel	Yes
Alarms	No
Control Functions	pH Adjustment

Alum Coagulation Tank pH Monitor

Range	5-9 pH
Local Monitor	Yes
Recording at Control Panel	Yes
Alarms	High and Low
Control Functions	None

Wet Well Level Transmitter

Range	0-100 Inches H_2O
Type	Pressure transmitter with bubble tube
Input	Air pressure equal to static head above submerged bubble tube
Output	3 to 15 psi air

Wet Well Level Indicating Controller

Type	Pneumatic
Scale Range	0-100
Input	3-15 psi air
Output	3-15 psi air
Output goes to	Wet well level control valves

Wet Well Level Control Valve (Normal Operating)

Size	8"
Type	Butterfly
Body Material	Cast iron/rubber seat
Disc Material	Stainless Steel
Body Rating	150 psi

Wet Well Level Control Valve (Normal Operating)
(Continued)

Actuator Type	Pneumatic diaphragm motor
Positioner	Yes
Input Range	3-15 psi
Failure Position	Closed
Operating Supply Pressure	20 psi

Wet Well Level Control Valve (Impounding)

Size	8"
Type	Butterfly
Body Material	Cast Iron/Rubber seat
Disc Material	Stainless steel
Body Rating	150 psi
Actuator Type	Pneumatic diaphragm motor
Positioner	Yes
Input Range	3-15 psi
Failure Position	Closed
Operating Supply Pressure	20 psi

Primary Unit Flow Transmitter

Range	0-24 inches water
Type	Pressure transmitter with bubble tube
Primary Element	Orifice holes in primary flow measuring tank
Input	Air pressure corresponding to static head above end of submerged bubble tube
Output	3-15 psi
Output goes to	Primary unit flow indicator, Pen No. 1 of wastewater flow recorder, primary unit flow integrator, final clarifier ratio station, primary clarifier alum ratio station, primary clarifier cationic polyelectrolyte ratio station, and primary clarifier anionic polyelectrolyte ratio station

Primary Unit Flow Integrator

Type	Pneumatic
Input	3-15 psi
Input from	Primary unit flow transmitter
Output	120 Volt AC pulse
Output goes to	Flow totalizer and automatic sampling system counter

Primary Unit Flow Indicator

Type	Pneumatic
Scale	0-100
Flow Corresponding to Scale	0-4,500 gpm
Input Signal	3-15 psi
Input Signal from	Primary unit flow transmitter
Output Signal	None

Wastewater Flow Recorder

Type	Multi-Pen, pneumatic
Scale Range	0-100
Flow Corresponding to Scale	0-4,500 gpm
Input Signal	3-15 psi
No. 1 Pen (Red) Signal from	Primary unit flow transmitter
No. 2 Pen (Blue) Signal from	Final clarifier flow transmitter
No. 3 Pen (Green) Signal from	Final effluent flow transmitter

Final Clarifier Flow Transmitter

Range	0-25 inches water
Type	Pressure transmitter with bubble tube
Primary Element	Orifice holes in final clarifier flow measuring tank
Input	Air pressure corresponding to static head above end of submerged bubble tube
Output	3-15 psi air

Final Clarifier Flow Ratio Station

Type	Pneumatic
Scale Range	0-3.0/0-100
Scale Indicates	Ratio/Primary unit flow
Flow Corresponding to Scale	0-4,500 gpm
Input Signal	3-15 psi
Input Signal from	Primary unit flow transmitter
Output Signal	3-15 psi
Output Signal goes to	Final clarifier flow indicating controller (Remote set point)

Final Clarifier Flow Indicating Controller

Type	Pneumatic
Scale Range	0-100
Scale Indicates	Set point/Final clarifier flow
Flow Corresponding to Scale	0-4,500 gpm
Inputs	Remote set point/Final clarifier flow
Input Signal	3-15 psi/3-15 psi
Output Signal	3-15 psi
Modes of Operation	Remote/Local

Final Clarifier Flow Control Valve

Size	8"
Type	Butterfly
Body Material	Cast iron/Rubber seat
Disc Material	Stainless steel
Body Rating	150 psi
Actuator Type	Pneumatic diaphragm motor
Positioner	Yes
Input Range	3-15 psi
Failure Position	Closed
Operating Supply Pressure	20 psi

Primary Clarifier Low Flow Transmitter

Primary Element	Orifice plate
Type	Differential pressure cell
Range	20-205 inches H_2O
Output Signal	3-15 psi

Primary Clarifier Low Flow Indicating Controller

Type	Pneumatic
Scale Range	0-100
Scale Indicates	Primary Clarifier Effluent Flow
Flow Corresponding to Scale	0-4,500 gpm
Input Signal	3-15 psi
Input Signal from	Primary clarifier low flow transmitter
Output Signal	3-15 psi
Modes of Operation	Automatic/manual

Primary Clarifier Low Flow Control Valve

Size	4"
Type	Butterfly
Body Material	Cast iron
Disc Material	Stainless steel
Seat Material	Rubber
Body Rating	150 psi
Actuator Type	Pneumatic diaphragm motor
Positioner	Yes
Input Range	3-15 psi
Failure Position	Closed
Operating Supply Pressure	20 psi

Primary Clarifier Alum Ratio Station

Type	Pneumatic
Scale Range	0-3.0/0-100
Scale Indicates	Ratio/Output
Input Signal	3-15 psi
Input Signal from	Primary clarifier flow transmitter
Output Signal	3-15 psi
Output Signal Goes to	Stroke length positioner primary unit alum metering pump

Primary Clarifier Anionic Polyelectrolyte Ratio Station

Type	Pneumatic
Scale Range	0-3.0/0-100
Scale Indicates	Ratio/Output
Input Signal	3-15 psi
Input Signal from	Primary clarifier flow transmitter
Output Signal	3-15 psi

Primary Clarifier Anionic Polyelectrolyte Ratio Station (Continued)

Output Signal Goes to	Stroke length positioner, primary coagulant aid metering pumps

Primary Clarifier Cationic Polyelectrolyte Ratio Station

Type	Pneumatic
Scale Range	0-3.0/0-100
Scale Indicates	Ratio/Output
Input Signal	3-15 psi
Input Signal from	Primary clarifier flow transmitter
Output Signal	3-15 psi
Output Signal Goes to	Stroke length positioner, primary cationic polyelectrolyte metering pump

Final Clarifier Alum Ratio Station

Type	Pneumatic
Scale Range	0-3.0/0-100
Scale Indicates	Ratio/Output
Input Signal	3-15 psi
Input Signal from	Final Clarifier flow transmitter
Output Signal	3-15 psi
Output Signal Goes to	Stroke length positioner, final clarifier alum metering pump

Final Clarifier Anionic Polyelectrolyte Ratio Station

Type	Pneumatic
Scale Range	0-3.0/0-100
Scale Indicates	Ratio/Output
Input Signal	3-15 psi
Input Signal from	Final clarifier flow transmitter
Output Signal	3-15 psi
Output Signal Goes to	Stroke length positioner, final coagulant aid metering pumps

Final Clarifier Cationic Polyelectrolyte Ratio Station

Type	Pneumatic
Scale Range	0-3.0/0-100
Scale Indicates	Ratio/Output
Input Signal	3-15 psi
Input Signal from	Final Clarifier flow transmitter
Output Signal	3-15 psi
Output Signal Goes to	Stroke length positioner, final clarifier cationic polyelectrolyte metering pump

Primary Clarifier Effluent Compartment Level Transmitter (or Clarified Effluent Level Transmitter)

Type	Pneumatic pressure transmitter with bubble tube
Range	0-38 Inches water
Input	Air pressure corresponding to static head above end of submerged bubble tube
Output	3-15 psi
Output Goes to	Primary clarifier effluent compartment level indicating controller

Primary Clarifier Effluent Compartment Level Indicating Controller (or Clarified Effluent Level Indicating Controller)

Type	Pneumatic
Scale Range	0-100
Input Signal	3-15 psi
Input Signal from	Primary clarifier effluent compartment level transmitter
Output Signal	3-15 psi
Output Signal Goes to	Primary clarifier effluent compartment level control valve

Primary Clarifier Effluent Compartment Level Control Valve

Size	8"
Type	Butterfly
Body Material	Cast iron
Disc Material	Stainless Steel
Seat Material	Rubber
Body Rating	150 PSI
Actuator Type	Pneumatic diaphragm motor
Positioner	Yes
Input Range	3-15 PSI
Failure Position	Closed
Operating Supply Pressure	20 PSI

Primary Clarifier Sludge Compartment Level Transmitter

Type	Pneumatic flange mounted differential pressure transmitter
Range	0-20 to 0-205 inches water
Input	Static level in vessel
Output Signal	3-15 PSI
Output Signal Goes to	Sludge compartment level indicator and pressure switches, pump start and stop

Final Clarifier Sludge Compartment Level Transmitter

Type	Pneumatic flange mounted differential pressure transmitter
Range	0-20 to 0-205 inches water
Input	Static level in vessel
Output Signal	3-15 PSI
Output Signal Goes to	Sludge compartment level indicator and pressure switches, pump start and stop

Sludge Compartment Level Indicator

Scale	0-100/0-100
Scale Indicates	Primary unit sludge level/Final unit sludge level
Input Signal	3-15 PSI/3-15 PSI

Sludge Compartment Level Indicator (Continued)

Input Signal from	
Red Pen (Right)	Primary clarifier sludge compartment level transmitter
Green Pen (Left)	Final clarifier sludge compartment level transmitter

Alum Serving Tank Level Transmitter

Type	Pneumatic flange mounted differential pressure transmitter
Range	0-20 to 0-205 inches water
Input	Static level in vessel
Output Signal	3-15 PSI
Output Signal Goes to	Alum serving tank level indicator and pressure switches (to fill tank and provide high and low level alarms)

Final Effluent Flow Transmitter

Type	Magnetic flow meter
Size	12 inch
Output	Converted to pneumatic (3-15 PSI)
Output Signal Goes to	Pen No. 3 of the wastewater flow recorder, flow integrator, flow totalizer and counter for the automatic sampling system

Alum Feed Rate Recorder

Type	4-Pen, pneumatic
Pen No. 1 (Red)	
Scale Range	0-400
Scale Indicates	Alum dosage to primary treatment in mg/l
Input Signal	3-15 PSI
Input Signal from	Ratio setting of primary clarifier alum ratio station

Alum Feed Rate Recorder (Continued)

Pen No. 2 (Green)	
Scale Range	0-100
Scale Indicates	Alum flow rate to primary treatment in GPH
Scale Multiplier	Times 0.5
Input Signal	3 - 15 PSI
Input Signal from	Primary clarifier alum ratio station output signal
Pen No. 3 (Blue)	
Scale	0-400
Scale Indicates	Alum dosages to final clarifier in mg/l
Input Signal	3-15 PSI
Input Signal from	Ratio setting of final clarifier alum ratio station
Pen No. 4 (Purple)	
Scale	0-100
Scale Indicates	Alum flow rate to final clarifier in GPH
Scale Multiplier	Times 0.5
Input Signal	3-15 PSI
Input Signal from	Final clarifier alum ratio station output signal

Cationic Polyelectrolyte Feed Rate Recorder

Type	4-Pen, pneumatic
Pen No. 1 (Red)	
Scale	0-30
Scale Indicates	Cationic Polyelectrolyte dosage to primary clarifier in mg/l
Input Signal	3-15 PSI
Input Signal from	Ratio setting of primary clarifier cationic polyelectrolyte ratio station
Pen No. 2 (Green)	
Scale	0-100
Scale Indicates	Cationic polyelectrolyte flow rate to primary clarifier in GPH
Scale Multiplier	Times 0.025

Cationic Polyelectrolyte Feed Rate Recorder (Continued)

Input Signal	3-15 PSI
Input Signal from	Primary clarifier cationic polyelectrolyte ratio station output signal
Pen No. 3 (Blue)	
Scale	0-30
Scale Indicates	Cationic polyelectrolyte dosage to final clarifier in mg/l
Input Signal	3-15 PSI
Input Signal from	Ratio setting of final clarifier cationic polyelectrolyte ratio station
Pen No. 4 (Purple)	
Scale	0-100
Scale Indicates	Cationic polyelectrolyte flow rate to final clarifier in GPH
Scale Multiplier	Times 0.025
Input Signal	3-15 PSI
Input Signal from	Cationic polyelectrolyte ratio station output signal

Anionic Polyelectrolyte Feed Rate Recorder

Type	4-Pen, pneumatic
Pen No. 1 (Red)	
Scale	0-1.4
Scale Indicates	Anionic polyelectrolyte dosage to primary clarifier in mg/l
Input Signal	3-15 PSI
Input Signal from	Ratio setting of primary clarifier anionic polyelectrolyte ratio station
Pen No. 2 (Green)	
Scale	0-100
Scale Indicates	Anionic polyelectrolyte flow rate to primary clarifier in GPH

Anionic Polyelectrolyte Feed Rate Recorder (Continued)

Scale Multiplier	Times 0.5
Input Signal	3-15 PSI
Input Signal from	Anionic polyelectrolyte ratio station output signal
Pen No. 3 (Blue)	
Scale	0-1.4
Scale Indicates	Anionic polyelectrolyte dosage to final clarifier in mg/l
Input Signal	3-15 PSI
Input Signal from	Ratio setting of final clarifier anionic polyelectrolyte ratio station
Pen No. 4 (Purple)	
Scale	0-100
Scale Indicates	Anionic polyelectrolyte flow rate to final clarifier in GPH
Scale Multiplier	Times 0.5
Input Signal	3-15 PSI
Input Signal from	Final clarifier anionic polyelectrolyte ratio output signal

Final Effluent Flow Transmitter

Type	Magnetic flow meter
Size	12 inch
Auxiliary Equipment	Magnetic to current converter, current to pneumatic converter, pneumatic flow integrator, flow totalizer, counter and timer
Output Goes to	Pen No. 3 of the wastewater flow recorder and automatic composite sampling system

Primary Clarifier Sludge Flow Meter

Type	Magnetic
Size	3 inch

Primary Clarifier Sludge Flow Meter (Continued)

Auxiliary Equipment	Magnetic to current converter, current to pneumatic converter, flow integrator, flow totalizer
Output Goes to	Primary unit sludge flow recorder

Final Clarifier Sludge Flow Meter

Type	Magnetic
Size	3 inch
Auxiliary Equipment	Magnetic to current converter, current to pneumatic converter, pneumatic flow integrator, flow totalizer
Output Goes to	Final clarifier sludge flow recorder

Primary Clarifier Sludge Flow Recorder

Type	Pneumatic
Input Signal	3-15 PSI
Input Signal from	Primary clarifier sludge flow meter

Final Clarifier Sludge Flow Recorder

Type	Pneumatic
Input Signal	3-15 PSI
Input Signal from	Final clarifier sludge flow meter

TABLE C-3

WATER QUALITY MONITORING INSTRUMENTS

Raw Wastewater pH Monitor

Range	2-12 pH
Local Monitor	Yes
Recording at Control Panel	Yes
Alarms	High and Low

Raw Wastewater Turbidity Meter

Range	0-200
Local Monitor	No
Recording at Control Panel	Yes
Alarms	No

Primary Clarifier Effluent Turbidity Meter

Range	0-50
Local Monitor	No
Recording at Control Panel	Yes
Alarms	No

Final Clarifier Effluent pH Monitor

Range	0-15 pH
Local Monitor	No
Recording at Control Panel	Yes
Alarms	No

Final Clarifier Effluent Turbidity Meter

Range	0-50
Local Monitor	No
Recording at Control Panel	Yes
Alarms	No

Final Clarifier Effluent Temperature Monitor

Range	0-150°F
Local Monitor	No
Recording at Control Panel	Yes
Alarms	No

Table C-3 (Continued)

Final Clarifier Effluent Dissolved Oxygen Monitor

Range	0-15 mg/l
Local Monitor	No
Recording at Control Panel	Yes
Alarms	No

Final Effluent pH Monitor

Range	2-12 pH
Local Monitor	Yes
Recording at Control Panel	Yes
Alarms	High and Low

Lagoon Water Dissolved Oxygen

Range	1-15 mg/l
Local Monitor	No
Recording at Control Panel	Yes
Alarms	No

Lagoon Water Temperature

Range	0-150°F
Local Monitor	No
Recording at Control Panel	Yes
Alarms	No

Lagoon Effluent Dissolved Oxygen Monitor

Range	0-15 mg/l
Local Monitor	No
Recording at Control Panel	Yes
Alarms	No

Lagoon Effluent Temperature Monitor

Range	0-150°F
Local Monitor	No
Recording at Control Panel	Yes
Alarms	No

APPENDIX D

EQUIPMENT AND CONSTRUCTION COSTS

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TABLE D-1

EQUIPMENT AND CONSTRUCTION COSTS

Item	Total Cost
Engineering	$144,538
Bar Screen	10,800
Raw Wastewater Pumps	23,000
Neutralization Facilities	72,100
Alum Coagulation Vessel	18,700
Chemical Serving Facilities	33,300
Clarifiers, Including Flow Measuring Boxes, Flash Mixing Tanks, Recycle Pumps, Pressure Retention Tank, Recycle Piping, and Clarifier Influent Lines	255,100
Clarified Effluent Pumps	9,700
Transfer Lines to and from Lagoon	52,400
Lagoon	50,600
Mechanical Aerators	69,100
Lagoon Effluent Pumps	13,500
Piping Within Treatment Area	234,200
Electrical -Treatment Area	150,355
Electrical -Lagoon Area	86,135
Instruments	53,700
Sludge Transfer Pumps	4,000
Sludge Transfer Piping	9,100
Sludge Loading Pump and Piping	5,100
Chemical Makeup Building	34,500
Domestic Water Supply Line	9,000
Sanitary Sewer	24,800
Trenches	94,300
Grading	14,500
Total	$1,472,528

APPENDIX E

LABORATORY TESTING EQUIPMENT

TABLE E-1

LABORATORY TESTING EQUIPMENT

Total Organic Carbon Analyzer	Beckman Model 915
BOD_5 Incubator	Lab Line 5, Cubic Foot
Dissolved Oxygen Meter	Delta Scientific Model 85
Portable pH Meters (2)	Corning Model 6
Laboratory pH Meter	Corning Model 7
Conductivity Meter	YSE Model 31
Colorimeter	B and L Spectronic 20
Turbidity Meter	Hellige
Manometric BOD_5 Apparatus	Hack
Gang Stirrer	Phipps-Bird, 6-Place
Air Flotation Test Kit	Permutit Company
Drying Oven	Blue M, 0 - 140° C
Vacuum Oven	National Model 5830
Muffle Furnaces (2)	Blue M Models M15-1A and M30A-1C
Electric Water Bath	Precision Scientific
Large Hot Plate	Lindberg Type H2
Electric Hot Plate	Thermostatic Thermolyne 1900
Balance	Mettle Model H10W
Electronic Calculator	Cannon Model No. 164-P
Refrigerator	Philco, 17 Cubic Foot
Laboratory Cupboards (2)	Curtin No. 872427